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A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABI--ETC(U)
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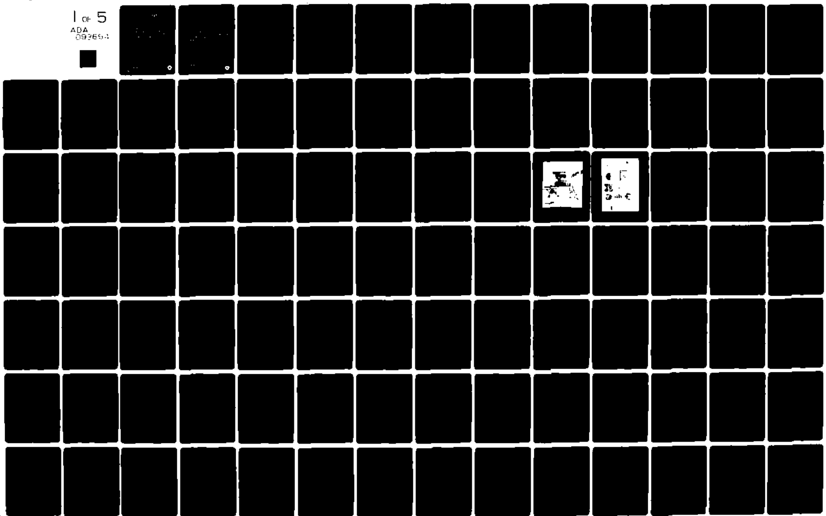

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LEVEL II

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A Piloted Simulator Investigation of Static Stability and Stability/Control Augmentation Effects on Helicopter Handling Qualities for Instrument Approach

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A Piloted Simulator Investigation of Static Stability and Stability/Control Augmentation Effects on Helicopter Handling Qualities for Instrument Approach

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SYMBOLS AND ABBREVIATIONS

$C_{1/2}$ cycles to damp to half amplitude

F_{AS} lateral cyclic stick force, lb

F_{ES} longitudinal cyclic stick force, lb

F_{RP} directional pedal force, lb

g acceleration of gravity, ft/sec^2

h altitude, ft

L'_v rolling moment due to side velocity with inertia cross product algebraically eliminated, $rad/sec^2/ft/sec$

$L'_{\delta_{AS}}$ rolling moment due to lateral cyclic stick with inertia cross product algebraically eliminated, $rad/sec^2/in.$

$L'_{\delta_{RP}}$ rolling moment due to directional pedal with inertia cross product algebraically eliminated, $rad/sec^2/in.$

L_ϕ rolling moment due to control feedback of roll attitude, $rad/sec^2/rad$

M_u pitching moment due to longitudinal velocity, $rad/sec^2/ft/sec$

M_w pitching moment due to vertical velocity, $rad/sec^2/ft/sec$

$M_{\delta_{ES}}$ pitching moment due to longitudinal cyclic stick, $rad/sec^2/in.$

M_θ pitching moment due to control feedback of pitch attitude, $rad/sec^2/rad$

N'_v yawing moment due to side velocity with inertia cross product algebraically eliminated, $rad/sec^2/ft/sec$

$N'_{\delta_{AS}}$ yawing moment due to lateral cyclic stick with inertia cross product algebraically eliminated, $rad/sec^2/in.$

$N'_{\delta_{RP}}$ yawing moment due to directional pedal with inertia cross product algebraically eliminated, $rad/sec^2/in.$

P_D	period of the damped oscillation, sec
p	roll rate about body axis, rad/sec
q	pitch rate about body axis, rad/sec
r	yaw rate about body axis, rad/sec
s	Laplace operator, 1/sec
T_D	time to double amplitude, sec
TDA	turn-following directional augmentation
u	body axis longitudinal velocity, ft/sec
u_g	random gust velocity along the x body axis, ft/sec
V	airspeed, knots
v	body axis side velocity, ft/sec
v_g	random gust velocity along the y body axis, ft/sec
w	body axis vertical velocity, ft/sec
w_g	random gust velocity along the z body axis, ft/sec
β	sideslip angle, deg
Δ_{AS}	lateral control input, in.
Δ_{AS}/p	lateral control input due to roll rate, in./rad/sec
Δ_{AS}/q	lateral control input due to pitch rate, in./rad/sec
Δ_{AS}/v	lateral control input due to side velocity, in./ft/sec
Δ_{AS}/δ_{AS}	lateral control gearing
Δ_{AS}/δ_{CS}	lateral control input due to collective stick cross-gearing

Δ_{AS}/δ_{ES} lateral control input due to longitudinal cyclic stick cross-gearing

Δ_{CS} collective control input, in.

Δ_{ES} longitudinal control input, in.

Δ_{ES}/p longitudinal control input due to roll rate, in./rad/sec

Δ_{ES}/q longitudinal control input due to pitch rate, in./rad/sec

Δ_{ES}/u longitudinal control input due to longitudinal velocity, in./ft/sec

Δ_{ES}/δ_{CS} longitudinal control input due to collective stick cross-gearing

Δ_{ES}/δ_{ES} longitudinal control gearing

Δ_{RP} directional control input, in.

Δ_{RP}/v directional control input due to side velocity, in./ft/sec

Δ_{RP}/δ_{CS} directional control input due to collective stick cross-gearing

δ_{AS} lateral cyclic stick displacement, in.

δ_{AS}/β Gradient of lateral cyclic displacement vs sideslip angle, in./deg

δ_{CS} collective stick displacement, in.

δ_{ES} longitudinal cyclic stick displacement, in.

δ_{ES}/V gradient of longitudinal cyclic displacement vs airspeed, in./knot

δ_{RP} directional pedal displacement, in.

δ_{RP}/β gradient of directional pedal displacement vs sideslip angle, in./deg

ζ damping ratio

θ pitch attitude, deg

λ root of characteristic equation

σ_{u_g} root-mean-square intensity of u_g, ft/sec

σ_{v_g} root-mean-square intensity of v_g, ft/sec

σ_{w_g} root-mean-square intensity of w_g, ft/sec

τ time constant, sec

ϕ roll angle, deg

ψ yaw angle, deg

ω_n undamped natural frequency, rad/sec

$(\dot{\ })$ derivative with respect to time, d/dt

$(\ )_{fb}$ feedback quantity

Subscripts:

b body axis system

c simulator cab axis system

m model match condition

o initial condition

p aircraft pilot station

s simulator drive axis system

s stability axis system

Abbreviations:

AC attitude command

CHPR Cooper-Harper pilot rating

FAR Federal Aviation Regulation

FSAA	Flight Simulator for Advanced Aircraft
IFR	instrument flight rules
IMC	instrument meteorological conditions
MSL	mean sea level
N	neutral
PR	pilot rating
RCAH	rate-command-attitude-hold
RDID	rate damped with input decoupling
S	stable
S.D.	standard deviation
VMC	visual meteorological conditions

A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABILITY/CONTROL AUGMENTATION EFFECTS ON HELICOPTER HANDLING QUALITIES FOR INSTRUMENT APPROACH

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SUMMARY

A motion-base simulator was used to compare the flying qualities of three generic single-rotor helicopters during a full-attention-to-flight control task. Terminal-area VOR instrument approaches were flown with and without turbulence. The objective of this NASA/FAA study was to investigate the influence of helicopter static stability in terms of the values of cockpit control gradients as specified in the existing airworthiness criteria, and to examine the effectiveness of several types of stability control augmentation systems in improving the instrument-flight-rules capability of helicopters with reduced static stability. Two levels of static stability in the pitch, roll, and yaw axes were examined for a hingeless-rotor configuration; the variations were stable and neutral static stability in pitch and roll, and two levels of stability in yaw. For the lower level of static stability, four types of stability and control augmentation were also examined for helicopters with three rotor types: hingeless, articulated, and teetering. Pilot rating results indicate the acceptability of neutral static stability longitudinally and laterally and the need for pitch-roll attitude augmentation to achieve a satisfactory system.

INTRODUCTION

The anticipated rapid expansion of civil helicopter operations has led to increasing efforts to assess problem areas in civil helicopter design, certification, and operation, and to apply new technology or concepts to resolve them. For example, the National Aeronautic and Space Administration (NASA) and the Federal Aviation Administration (FAA) have recently initiated long-term research efforts for helicopters (e.g., ref. 1). One area of particular interest is the improvement of instrument flight capabilities at low altitudes in all weather conditions. Of concern are the influences of the helicopter's inherent flight dynamics, flight-control system, and display complement on flying qualities for instrument-flight-rules (IFR) flight, both in terms of design parameters to ensure a good IFR capability, and with regard to the characteristics that should be required for certification.

As a part of their respective research programs, NASA and the FAA have instituted a joint program at Ames Research Center to investigate helicopter IFR certification criteria. This series of investigations has the following two general goals:

1. Provide analyses and experimental data to ascertain the validity of the Airworthiness Criteria for Helicopter Instrument Flight (ref. 2) being proposed as an appendix to FAR Parts 27 and 29 (refs. 3, 4).

2. Provide analyses and experimental data to determine the flying qualities, flight control, and display aspects required for a good helicopter IFR capability, and to relate these aspects to design parameters of the helicopter.

With respect to the first goal, the criteria of reference 2 are to some extent an amalgam of previous handling-qualities requirements for military aircraft (in particular MIL-F-8501A, ref. 5); it is important to update the substantiation of the quantitative aspects of these criteria and to ascertain their validity for civil applications. With respect to the second goal, a recent simulation experiment at Ames Research Center showed that a flight-control system including an attitude command stability control augmentation system (SCAS) was required to obtain pilot ratings of "satisfactory" for IFR terminal-area operation (ref. 6). This result corroborates the fact that advanced SCAS or displays or both are used in most helicopters currently certificated for single-pilot IFR operations (ref. 7). It is important that the basic trade-offs in inherent dynamics, SCAS design, and display sophistication be defined so that the extent to which this result is uniformly applicable can be determined.

Accordingly, the experiment described in this report was designed to address some aspects of the existing certification criteria as well as some further aspects of the control system effects. Specifically, the experiment was designed to focus on the influence of helicopter static stability in terms of the values of control gradients required in the reference 2 criteria, and to examine the efficacy of several types of SCAS in improving the IFR capability of helicopters with reduced static stability. Cooper-Harper pilot ratings were obtained from four pilots for a variety of values of these parameters, as the parameters influenced the performance and workload of a non-precision 60-knot IFR approach task, with and without simulated turbulence. The Flight Simulator for Advanced Aircraft (FSAA) at Ames Research Center was used in conjunction with a generic nine-degree-of-freedom helicopter mathematical model to implement and examine the experimental configurations.

The remainder of this report is organized as follows. The next section summarizes the motivation for the selection of the variables that were examined, and the following two sections describe the design of the experiment and its conduct. Flying-qualities results and measured performance and control usage indices are discussed in the fourth and fifth sections; conclusions and recommendations are presented in the final section. Supporting data — data summary, pilot comments, performance and control usage measures, and FSAA motion system drive logic — are presented in the appendixes.

BACKGROUND

This experiment was designed to address the suitability of several helicopter characteristics for flight under instrument meteorological conditions (IMC) in terminal areas. In particular, characteristics relative to civil certification by the FAA for IFR flight are of interest. In this context, the recently issued Airworthiness Criteria for Helicopter Instrument Flight (ref. 2) form a basis from which to select for investigation characteristics whose "suitable" values require definition or substantiation. To provide an understanding of the reasons behind the selection of experimental variables for this experiment, therefore, pertinent aspects of the criteria, recent research, and general considerations relative to them are reviewed here.

FAA airworthiness standards for helicopters do not include specific requirements for instrument flight (refs. 3, 4). Instead, paragraphs 27.141 and 29.141 of the Federal Aviation Regulations (FAR's) of references 3 and 4 include the following general statement: "The rotorcraft must have any additional characteristics required for night or instrument operation, if certification for those kinds of operation is requested." To qualify this statement, the FAA issued a set of criteria (ref. 8) to serve as a guide when IFR certification was being sought; the set includes one version of these "interim" criteria, which were used throughout the 1960's and 1970's. In terms of flight dynamics, the criteria included some attempts to quantify suitable values for several helicopter characteristics that would ensure adequate flying qualities in IMC conditions; for example, static control position and force gradients and damping characteristics of oscillatory roots. In December 1978, a final version of these criteria was issued (ref. 2). Prior to incorporating the criteria, either as amendments to the FAR or as updated demonstration requirements, it is necessary to ensure their applicability and validity for the helicopter IFR situation.

As formulated in reference 2, the criteria are broken into nine sections and an appendix. The general contents of the nine sections are described below:

1. General: Permits certification of an instrument flight envelope that is more restrictive than the VMC envelope.

2. Trim: Requires capability to achieve zero control forces in steady-state flight. Requires cyclic control to exhibit self-centering tendency.

3. Static longitudinal stability: Requires (for normal category single-pilot and all transport category) stable longitudinal control force with airspeed characteristics. Requires "clearly perceptible" force change for 20-knot speed change.

4. Static lateral-directional stability: Requires stable lateral control force and position with sideslip and stable directional control position with sideslip.

5. Longitudinal-lateral-directional dynamic stability: Requires (for normal category single-pilot and all transport category) damping of oscillatory modes, depending on frequency, as per the IFR requirements of MIL-F-8501A (refs. 5, 7). Requires that aperiodic responses "should not be objectionable."

6. Stability augmentation: Requires, among other things, that aircraft will meet existing visual flight rules (VFR) FAR's after failure of the stability augmentation system (SAS). Requires failure simulation with prescribed response delay times..

7. Controllability: Requires no "dangerous" divergence following engine failure. Requires no "objectionable" cross-coupling. Requires no tendency for pilot-induced oscillations.

8. Equipment, system, and installations: Requires instruments in addition to those required by FAR 29.1303. Discussion on power sources for instruments.

9. IMC evaluation: Requires a total of at least 5 hr of operation in actual IMC in the ATC system.

Appendix. Criteria for evaluating in turbulence: Requires evaluation of effects on precision flight and pilot workload in turbulence "expected in normal IFR flight."

Note that these criteria are to be met in addition to the flight characteristics standards for VFR flight specified in FAR's 27 and 29.

Among these criteria, the sections dealing with static and dynamic stability attempt to quantify values for several characteristics of the helicopter as being required for IFR flight. It is important to ascertain:

1. Whether the helicopter IFR flying qualities are in fact sensitive to the characteristics selected to be quantified

2. Whether the values specified for the characteristics are appropriate

3. Whether additional characteristics, not currently quantified, also need specification to ensure safe IFR flying qualities.

In the experiment described herein these questions are addressed for the criteria on the static control position and force gradients given in sections 3 and 4 of reference 2. Although the statics and dynamics of an aircraft are not independent of each other, it is generally possible to consider variations in one somewhat independently of the other. Because fewer data relevant to helicopters exist and because the carry-over of the control gradient concepts to helicopters from fixed-wing aircraft requires validation, it was considered appropriate that the influence of the static criteria be examined first.

With respect to the criteria on control position and force gradients, therefore, it is useful to examine the relationships involved on a simplified basis and what they imply. Consider initially the longitudinal control position gradient with forward velocity. Assuming for conciseness that the longitudinal and lateral-directional motions are uncoupled and that trim pitch attitude is small so that $g \sin\theta_o$ is negligible, and assuming no attitude augmentation, the change in longitudinal stick position with speed at constant power is[1]:

$$\frac{d\delta_{ES}}{dV} = \frac{M_w Z_u - M_u Z_w}{Z_w M_{\delta_{ES}} - M_w Z_{\delta_{ES}}} \tag{1}$$

This expression is just the reciprocal of the steady state response of velocity to a longitudinal input. The numerator of equation (1) is, therefore, the constant coefficient of the longitudinal characteristic equation (divided by g); under most conditions, the sign of this term indicates the presence or absence of an unstable aperiodic root. Static stability implies that this term is positive, neutral stability implies it is zero, and a static instability generally implies that it is negative. If the sign of the denominator of equation (1) is conventional (negative) then a negative stick position gradient (forward stick for increasing speed) is a direct indication of the static stability of the aircraft. Although it is theoretically possible to have (a positive) stick gradient for a stable value of $Z_u M_w - M_u Z_w$ (>0) by having a positive value for the denominator of equation (1) ($Z_w M_{\delta_{ES}} - M_w Z_{\delta_{ES}}$), for helicopters this circumstance requires an unrealistically high (and unstable) M_w or an unrealistically high ratio of $Z_{\delta_{ES}}/M_{\delta_{ES}}$ or both. Hence, the sign of the stick position gradient will, in general, correspond to the presence or absence of longitudinal "static" stability.

The point of interest for helicopters is that the static stability arises in a different way than for conventional aircraft. For a rigid fixed-wing airplane with no power effects, $M_u \doteq o$, and, for $|Z_{\delta_{ES}} M_w| << |Z_w M_{\delta_{ES}}|$, the control position gradient is:

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[1]The equations in this report are written in a general body-fixed axis system. For simplicity in discussing basic aspects of the problem, however, the simplifying assumptions of $\phi_o \doteq \theta_o \doteq o$ will occasionally be introduced.

$$\left.\frac{d\delta_{ES}}{dV}\right|_{M_u=0} \doteq +M_w\left(\frac{Z_u}{Z_w M_{\delta_{ES}}}\right) \quad (2)$$

In this case, the position gradient is determined by the angle-of-attack stability. For a single-rotor helicopter, however, the angle-of-attack stability is very small (particularly without a horizontal tail surface); for $M_w \doteq 0$ and $|Z_{\delta_{ES}} M_w| << |Z_w M_{\delta_{ES}}|$, the control position gradient is therefore:

$$\left.\frac{d\delta_{ES}}{dV}\right|_{M_w=0} = -M_u\left(\frac{1}{M_{\delta_{ES}}}\right) \quad (3)$$

For the helicopter, with no attitude augmentation, the position gradient is primarily determined by the velocity stability term (M_u) rather than by M_w. This difference has the following implications for the two simplified situations given in equations (2) and (3):

1. For the airplane, the control position gradient depends on angle-of-attack stability and therefore the slope is dependent on the center-of-gravity position (the static margin). For the simplified helicopter (no tail or fuselage effects, no hinge offsets or restraints), the control gradient depends on velocity stability and the slope is, to first order, independent of center-of-gravity position.

2. The influence of the static stability on the dynamic characteristics is markedly different in the two cases. For the airplane ($M_w < 0$, $M_u \doteq 0$), increasing the static stability (a more negative control position gradient) will generally not lead to a divergent oscillation, but, for the helicopter ($M_u > 0$, $M_w \doteq 0$), increasing the static gradient will, in general, lead to an oscillation that is divergent. Hence, for airplanes, a very stable gradient may be desirable (control authority or gust sensitivity questions aside) because it will also indicate dynamic stability, but the same gradient may not be desirable for the helicopter because of the oscillatory instability.

The concepts of stick-free stability, and therefore of control-force gradient, also are different longitudinally for the airplane and the helicopter. The classical airplane concept of stick-free stability for an unboosted control system, which depends on elevator hinge moments and floating tendencies and may be different than the stick-fixed stability, is not really germane to the helicopter because almost all helicopters use boosted (irreversible) control systems; effectively, therefore, the stability is the same stick-fixed and stick-free for helicopters (assuming no use of devices such as bobweights or downsprings) as it is for airplanes with boosted control systems without control system devices. Assuming the absence of devices such as bobweights, downsprings, or g-feel programming, therefore, the control-force gradient for helicopters is directly related to the control-position gradient through the characteristics of the feel system (centering springs, etc.). In this situation, the requirement for a stable longitudinal control-force gradient implies a stable longitudinal position gradient also.

Since very low or even zero forces are frequently considered desirable for low-speed and hover flight in visual conditions, however, it is of interest to ascertain whether stable force gradients — in particular, force-feel systems — are necessary in addition to position gradients for helicopter IMC operations.

Because of the relationships between the longitudinal gradients and the longitudinal static stability, flying-qualities specifications generally require the gradients to be stable. The applicable requirements from various specifications are as follows:

Airworthiness Criteria (ref. 2)	Stable stick force gradient with speed
MIL-F-8785B (ref. 10)	Stable stick force and position gradients with speed (Level 1)
MIL-F-8501A (ref. 5)	Stable stick force and position gradients with speed
MIL-F-83300 (ref. 9)	Stable or neutral stick force and position gradients with speed and attitude (Level 1)

Note that MIL-F-83300 explicitly permits a neutral gradient because rate-command-attitude-hold SCAS's result in this type of characteristic. Most of the applicable flying-qualities data to support these requirements for helicopters are discussed in references 9 and 11. As pointed out in reference 11, there are some discrepancies in the conclusions drawn concerning these data: The discrepancies concern the relative importance of force or position stability and the amount of instability permissible.

The most recent helicopter IFR flying-qualities data in this regard are from a ground simulation experiment conducted at Ames Research Center (ref. 6). In that experiment, an exploratory investigation of variations in the longitudinal control-position/force gradient was made for a hingeless-rotor helicopter; two stable values and one neutral value were evaluated in simulated IFR conditions. It was the opinion of the pilot that some level of stable stick-force gradient was needed. However, the experiment also considered four levels of SCAS applied to three types of helicopter rotors — teetering, articulated, and hingeless — and a feature in the SCAS design led to additional variations in the longitudinal gradient ranging from stable to unstable among the rotor types. Although it must be remembered that other flying-qualities parameters were also varying among these configurations, it did turn out that although the only configurations rated satisfactory (PR $\leq 3\frac{1}{2}$) had stable longitudinal control position and force gradients, a low level of unstable gradients was rated as acceptable (PR $\leq 6\frac{1}{2}$) in some cases. It was to examine the question of longitudinal gradients in a more constrained fashion that these parameters were selected as one of the variables in the experiment reported here.

Consider now the relationships involved in the lateral and directional control gradients with sideslip. In this case, both lateral and directional controls are changed to achieve straight and level flight at a constant sideslip angle. Assuming, for conciseness, no coupling to the longitudinal degrees of freedom, the control-position gradients with sideslip are (e.g., ref. 12):

$$\frac{\delta_{AS}}{\Delta v} = \frac{-L'_v N'_{\delta_{RP}} + N'_v L'_{\delta_{RP}}}{L'_{\delta_{AS}} N'_{\delta_{RP}} - N'_{\delta_{AS}} L'_{\delta_{RP}}} \tag{4}$$

$$\frac{\delta_{RP}}{\Delta v} = \frac{-N'_v L'_{\delta_{AS}} + L'_v N'_{\delta_{AS}}}{L'_{\delta_{AS}} N'_{\delta_{RP}} - N'_{\delta_{AS}} L'_{\delta_{RP}}} \tag{5}$$

It is important to note that neither equation (4) nor (5) includes a term that is directly indicative of an unstable aperiodic root, as is the case with the longitudinal gradient (eq. (1)). In the simple case of small cross-coupling, the lateral gradient is a measure of the effective dihedral, and the directional gradient is a measure of the directional ("weathercock") stiffness. In the general cases given by equations (4) and (5), however, it is possible that having these gradients stable would not necessarily imply stable values for L'_v or N'_v because of the cross-coupling effects. A stable (positive) value of N'_v is important in control of sideslip during turning maneuvers, for example. Somewhat stable values of L'_v (negative) are usually considered desirable because of spiral mode stability, increased Dutch roll frequency, and the capability to "pick up a wing with rudder." For helicopters, however, the spiral mode is generally more stable than the fixed-wing case because of much smaller L'_r (ref. 11), and it is not clear that picking up a wing with the rudder is necessary for the helicopter terminal-area approach; hence, the necessity for stable L'_v is not as clear as it is for N'_v.

The applicable requirements on the lateral and directional control position and force gradients from various specifications are as follows:

Airworthiness Criteria (ref. 2)	Lateral force and position gradients with sideslip stable: Directional position gradients with sideslip stable.
MIL-F-8785B (ref. 10)	Lateral and directional force and position gradients with sideslip stable (Level 1).
MIL-F-8501A (ref. 5)	Lateral and directional position and force gradients with sideslip stable.
MIL-F-83300 (ref. 9)	Lateral and directional position and force gradients with sideslip stable (Level 1).

The specifications can be seen to be in general agreement concerning the necessity of stable values for these gradients. Nonetheless, most of the data substantiating these requirements were derived from fixed-wing experiments, and there are some questions raised by data discussed in reference 9 concerning the need for stable effective dihedral. For this reason, a neutral lateral gradient was selected as one of the variables in this experiment.

With regard to ascertaining the possible influence on helicopter IMC flying qualities in the terminal area of the three control-position gradients and the three control-force gradients discussed in the preceding paragraphs, and thereby determining the suitability of the airworthiness criteria, a question of interest is also whether the combination of two or more gradients with "undesirable" values results in a significant degradation in flying qualities. In general, flying-qualities influences of a single parameter are investigated with other parameters at "good" values. By implication, therefore, if an aircraft design results in a marginal value for one of the parameters, it is necessary that the others be "good" for the flying qualities to remain at the desired level. To investigate this question, the variations in the control gradients that were designed for this experiment (see the following section of this report) were investigated both singly and in combination.

The other major set of variables in this experiment concerned the type of SCAS used and its influence on the IMC flying qualities. These configurations do not specifically address the airworthiness criteria of reference 2, which relate primarily to the influence on the flying qualities of an SCAS failure; to the extent that the SCAS is used to meet or improve upon the static or dynamic stability criteria, however, the data are also applicable to these aspects.

The reason for this part of the investigation is that essentially all helicopters currently certificated for single-pilot IFR operations include an SCAS. A recent flying-qualities ground simulation experiment conducted at Ames Research Center demonstrated why the SCAS's are so widely used. In that experiment three generic helicopter models incorporating three different types of rotors were examined in both visual meteorological conditions (VMC) and IMC using four different levels of SCAS: (1) none, (2) rate damping in pitch/roll/yaw, (3) rate damping in pitch/roll/yaw plus control input decoupling (primarily the collective), and (4) attitude command in pitch/roll, rate damping in yaw, and input decoupling (ref. 6). It was found that for IMC operations some level of SCAS above the bare airframe was necessary to ensure pilot ratings of acceptable (PR < 6½) for all three baseline configurations; in fact, only one of the rotor configurations, and that with only the highest level of SCAS, was rated satisfactory (PR < 3½). Because of cost, control authority, and reliability factors introduced by the SCAS, it is important to examine these results further, as well as to consider additional SCAS concepts, prior to initiating a study of the influence of failures. For this reason, the SCAS types described in the next section of this report were designed for investigation in this experiment to amplify and extend the results of reference 6.

DESIGN OF EXPERIMENT

This experiment was designed to focus attention on three areas that are of concern in helicopter IFR terminal-area operations:

1. The influence of static stability as evidenced by control position and force gradients for the three rotational degrees of freedom.

2. The efficacy of various types of stability and control augmentation for the three rotational degrees of freedom.

3. The effect of turbulence as a function of static stability and stability and control augmentation.

The evaluation configurations discussed in this section were designed to address these areas in a manner consistent with the following constraints:

1. As much as possible, the characteristics of each configuration, other than the ones specifically under investigation, were designed to meet the criteria given in the new FAA Airworthiness Criteria for Helicopter Instrument Flight (ref. 2).

2. The range of characteristics covered by all the configurations was designed to provide an expected range of Cooper-Harper pilot ratings from approximately 2 to 8 in order to ensure a valid flying-qualities experiment.

3. To provide a consistency check between the experiments, the configurations were selected to overlap those investigated in the previous simulation at Ames Research Center (ref. 6).

The remainder of this section discusses the design aspects relevant to each of the three areas listed above, and documents the resulting characteristics. Additional configuration characteristics are given in appendix A.

Static Gradient Configurations

To examine the influence of parameter variations on pilot rating, it is desirable that the baseline configuration from which the variations are made have flying qualities that are as good as possible to enhance the sensitivity of the ratings to the variations. The characteristics of the configurations also need to be selected such that (1) the variables of interest will not be masked by other design elements (e.g., augmentation that tends to minimize the effect of the variables being examined), and (2) the changes to the variables of interest do not introduce undesirable values of other characteristics (e.g., reduced damping ratios of oscillatory roots).

On these bases, a hingeless-rotor helicopter configuration from the previous piloted simulation experiment at Ames Research Center (ref. 6) was selected as the baseline for the static gradient investigations. This configuration, designated F32 in the previous experiment, employed rate damping plus input decoupling augmentation; it received better ratings for an instrument VOR task than any of the other rotor configurations (that used the same type of augmentation) in that experiment ($3.5 \leq PR \leq 4.5$ for two pilots). The rate damping augmentation has no effect on static stability and yet can be tailored to maintain most aspects of the dynamic stability within the guidelines given by the Airworthiness Criteria; input decoupling can have an effect on effective longitudinal velocity stability if gains to the longitudinal control are scheduled with speed (ref. 6), but this effect can be compensated for by an equivalent feedback of longitudinal velocity.

This baseline hingeless-rotor configuration is designated S01 in this experiment. Figure 1 is a schematic diagram of the way the configurations are set up in the simulator. The rotorcraft model — which includes three-degree-of-freedom tip-path-plane dynamics and six-degree-of-freedom rigid-body dynamics — has been used in several previous helicopter simulations at Ames Research Center (refs. 6, 13, 14). A description of this helicopter simulation model is given in reference 15. By selecting geometric and aerodynamic characteristics of the fuselage-empennage, and rotor design parameters, such as flapping-hinge restraint, flapping-hinge offset, blade Lock number, and blade pitch-flap coupling (δ_3), a variety of baseline helicopter configurations representative of several classes of existing machines can be set up. For the hingeless-rotor configuration used to investigate static gradients in this experiment, these geometric-aerodynamic characteristics were the same as those for the hingeless-rotor configurations in reference 6. These design parameters are representative of, for example, the BO-105 class of helicopter (ref. 16), as is discussed in reference 6, and were maintained constant for configurations S01-S08 and S13-S20. Table A4 of appendix A summarizes these parameters.

As is shown in figure 1, the simulation model also incorporates full-state feedback to all of the controllers plus input gearings and cross-gearings. These feedback and feed-forward gains can be used to tune some of the stability and control characteristics provided by the basic aerodynamic and geometric design parameters, and to implement a variety of SCAS concepts or to vary selected stability-control parameters directly, as is done with a variable stability aircraft.

For the static gradient investigations, an SCAS essentially identical to the rate damping-plus-input-decoupling system in reference 6 was implemented; it was held constant for all the static gradient variations. Appendix A summarizes the resulting equivalent angular derivatives and input control derivatives for these configurations; table A-6 of appendix A presents the tuning and SCAS gains that were used. Cross-gearings Δ_{ES}/δ_{CS}, Δ_{AS}/δ_{CS}, Δ_{RS}/δ_{CS}, and Δ_{AS}/δ_{ES} were used to reduce angular acceleration input coupling of pitch-to-collective, roll-to-collective, yaw-to-collective, and roll-to-pitch input, respectively. The control sensitivities of the pitch and roll sticks (Δ_{ES}/δ_{ES} and Δ_{AS}/δ_{AS}) were reduced approximately 20% from the values used previously; the reductions were made on the basis of pilot comments during the experiment checkout. Cross-feedback gains (Δ_{ES}/p and Δ_{AS}/q) were used to reduce rotor-caused pitch-to-roll-rate and roll-to-pitch-rate coupling caused

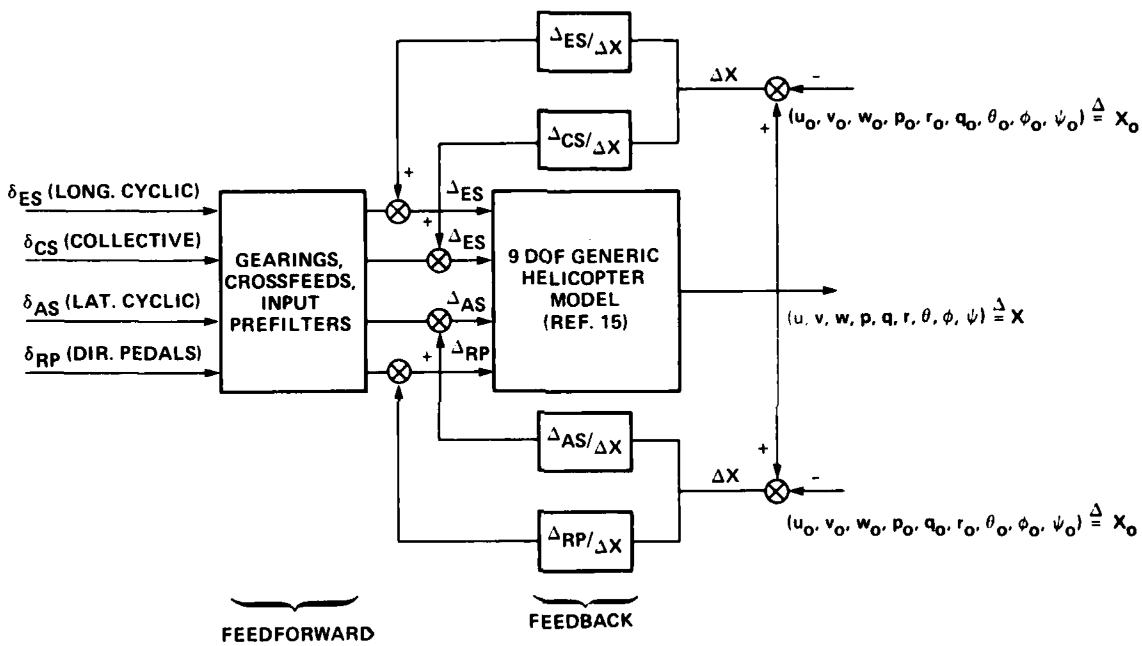


Figure 1.- Schematic diagram of simulation mathematical model.

by this rotor configuration (ref. 14), and the SAS rate gains (Δ_{ES}/q and Δ_{AS}/p) were relatively low due to the high inherent pitch and roll damping given by this rotor system.

Given the baseline aerodynamic-geometric parameters and the rate-damping/input-decoupling SCAS design discussed above, variations in static stability were addressed as evidenced by control position gradients for changes around trimmed flight. As will be described below, two levels of position and force gradients in each rotational axis were designed for examination singly and in combination. The configuration identifiers are summarized in table 1:

TABLE 1.- STATIC GRADIENT CONFIGURATION IDENTIFIERS

Configuration	Longitudinal gradient	Latitudinal gradient	Directional gradient
S01(S13)	Stable	Stable	Stable 1
S02(S14)	Neutral	Stable	Stable 1
S03(S15)	Stable	Neutral	Stable 1
S04(S16)	Neutral	Neutral	Stable 1
S05(S17)	Stable	Stable	Stable 2
S06(S18)	Stable	Neutral	Stable 2
S07	Neutral	Stable	Stable 2
S08	Neutral	Neutral	Stable 2

As will also be described, the configurations enclosed in parentheses in table 1 had the same control position gradients as their counterparts among S01-S08, but no force gradients at all; configurations S01-S08 had a fixed control-force-to-control-displacement relationship through the simulator's force-feel system. The design details for the control gradient investigations are summarized in the following paragraphs.

The expression (eq. (1)) for longitudinal stick changes with speed at a constant power setting, assuming no coupling to the lateral-directional degrees of freedom, was given in the last section (in terms of stability and control derivatives, and assuming for simplicity that $\theta_o \doteq 0$). Equation (1) is repeated here for convenience.

$$\frac{d\delta_{ES}}{dV} = \frac{M_w Z_u - M_u Z_w}{Z_w M_{\delta_{ES}} - M_w Z_{\delta_{ES}}}$$

As was discussed in the previous section, the Airworthiness Criteria require a "clearly perceptible" stable stick force gradient with velocity. An obvious choice of variations, therefore, is to change from a clearly perceptible stable gradient to either a neutral or an unstable gradient. Since an unstable position gradient will correspond to an aperiodic unstable root in the characteristic equation (as discussed above) this variation was not included in this experiment. The entire question of "how much" unstable aperiodicity is not objectionable remains a research topic of interest; the only guidance given in the Airworthiness Criteria is that it not be objectionable. A neutral gradient can be achieved, however, without violating the dynamic criteria; it is of interest because it is not clear that a neutral static margin should be excluded for helicopter IFR, given the inherent wide margins of airspeed and angle-of-attack excursions, without concern for stall. As will be discussed below, in this experiment the question of force gradients versus position gradients was addressed by implementing two position gradients and then examining each with the control loader force-feel ON, and with a "limp stick" (no force gradient or friction). Hence, designing two position gradients implies a stable and a neutral force gradient with force-feel ON, given a prescribed stick force-displacement relationship.

The variations in the longitudinal gradient were made through the use of longitudinal velocity perturbation feedback to the longitudinal control, thereby changing the derivative M_u in the numerator of equation (1). As was discussed in the previous section, for helicopters it is the M_uZ_w term that has the major influence on the longitudinal gradient rather than the M_wZ_u term typical of fixed-wing aircraft. For the hingeless-rotor configuration employing input decoupling scheduled with speed, the relative sizes are $M_uZ_w = -0.0011$ and $M_wZ_u = -0.000007$. Clearly, M_u has the major effect. The desired feedback turns out to be simply the change in gearing that is desired, as can be seen from:

$$\left.\frac{d\delta_{ES}}{dV}\right|_o = \frac{(Z_uM_w - M_uZ_w)_o}{Z_wM_{\delta_{ES}} - M_wZ_{\delta_{ES}}}$$

$$\left.\frac{d\delta_{ES}}{dV}\right|_m = \frac{(Z_uM_w - M_uZ_w)_o + \Delta(Z_uM_w - M_uZ_w)}{Z_wM_{\delta_{ES}} - M_wZ_{\delta_{ES}}} \qquad (6)$$

For δ_{ES}/u feedback:

$$\Delta(Z_uM_w - M_uZ_w) = Z_{\delta_{ES}}\left(\frac{\delta_{ES}}{u}\right)_{fb}M_w - M_{\delta_{ES}}\left(\frac{\delta_{ES}}{u}\right)_{fb}Z_w \qquad (7)$$

Hence:

$$\left.\frac{d\delta_{ES}}{dV}\right|_m = \left.\frac{d\delta_{ES}}{dV}\right|_o - \left(\frac{\delta_{ES}}{u}\right)_{fb} \tag{8}$$

and

$$\left(\frac{\delta_{ES}}{u}\right)_{fb} = \left.\frac{d\delta_{ES}}{dV}\right|_o - \left.\frac{d\delta_{ES}}{dV}\right|_m$$

(It may be easily verified that equation (8) holds when $\theta_o \neq 0$ also.)

The baseline hingeless configuration with input decoupling from the previous experiment had a stable gradient of -0.047 in./20 knots at 60 knots and of approximately neutral at 80 knots. To ensure a "clearly perceptible" gradient for the baseline configuration of this current experiment (S01), as well as the other static gradient configurations incorporating a stable longitudinal gradient (S03, S05, S06), stabilizing feedback of δ_{ES}/u was used. A gradient of roughly -0.65 in./20 knots at 60 knots was selected, based on a brief exploration in the previous experiment plus pilot comments during the checkout phase of this experiment. To provide an approximately neutral gradient over the range of flight speeds expected during the conduct of the evaluation task, the destabilizing feedback gain of δ_{ES}/u was scheduled with velocity for those configurations investigating a neutral longitudinal gradient (S02, S04, S07, S08). The gains are summarized in appendix A.

For the lateral and directional gradients, the expressions of interest are the combined control inputs required to maintain a constant sideslip in straight, level flight. As was shown in the previous section, the control gradient expressions are then given by:

$$\frac{\delta_{AS}}{v} = \frac{-L'_v N'_{\delta_{RP}} + N'_v L'_{\delta_{RP}}}{L'_{\delta_{AS}} N'_{\delta_{RP}} - N'_{\delta_{AS}} L'_{\delta_{RP}}} \tag{9}$$

$$\frac{\delta_{RP}}{v} = \frac{-N'_v L'_{\delta_{AS}} + L'_v N'_{\delta_{AS}}}{L'_{\delta_{AS}} N'_{\delta_{RP}} - N'_{\delta_{AS}} L'_{\delta_{RP}}} \tag{10}$$

It is noted that, unlike the expression for the longitudinal stick gradient, equations (9) and (10) do not explicitly contain a term corresponding to the presence or absence of an unstable aperiodic root. Hence, the stability characteristics must be checked separately.

As with feedback to change the longitudinal position gradient, the required feedback of lateral velocity (sideslip) to either the roll or the directional control is easily shown to be the desired gradient change of lateral stick or directional pedal to sideslip, respectively. It is also easily shown that, for example, feedback to the directional control causes no change to the lateral gradient:

$$\Delta\left(\frac{\delta_{AS}}{v}\right) = \frac{(-\Delta L'_v)N'_{\delta_{RP}} + (\Delta N'_v)L'_{\delta_{RP}}}{L'_{\delta_{AS}}N'_{\delta_{RP}} - N'_{\delta_{AS}}L'_{\delta_{RP}}} \qquad (11)$$

$$\text{for } \Delta AS/v \text{ feedback:} \quad \Delta L'_v = \frac{\Delta_{AS}}{v} L'_{\delta_{AS}}, \quad \Delta N'_v = \frac{\Delta_{AS}}{v} N'_{\delta_{AS}}$$

$$\text{for } \Delta RP/v \text{ feedback:} \quad \Delta L'_v = \frac{\Delta_{RP}}{v} L'_{\delta_{RP}}, \quad \Delta N'_v = \frac{\Delta_{RP}}{v} N'_{\delta_{RP}}$$

Then:

$$\Delta\left(\frac{\delta_{AS}}{v}\right) = \left(\frac{\Delta_{AS}}{v}\right) \frac{-L'_{\delta_{AS}}N'_{\delta_{RP}} + N'_{\delta_{AS}}L'_{\delta_{RP}}}{L'_{\delta_{AS}}N'_{\delta_{RP}} - N'_{\delta_{AS}}L'_{\delta_{RP}}} = -\left(\frac{\Delta_{AS}}{v}\right) \qquad (12a)$$

$$\Delta\left(\frac{\delta_{AS}}{v}\right) = \left(\frac{\Delta_{RP}}{v}\right) \frac{-L'_{\delta_{RP}}N'_{\delta_{RP}} + N'_{\delta_{RP}}L'_{\delta_{RP}}}{L'_{\delta_{AS}}N'_{\delta_{RP}} - N'_{\delta_{AS}}L'_{\delta_{RP}}} = 0 \qquad (12b)$$

It is evident from these equations that L'_v is the major contributor to δ_{AS}/v and N'_v to δ_{RP}/v; hence, changes to δ_{AS}/v affect primarily the dihedral effect, and changes to δ_{RP}/v affect primarily the directional stiffness.

The relationship between the static and dynamic characteristics is unfortunately more complex in the lateral-directional case than it is longitudinally. In the longitudinal case, a change in the stick gradient through M_u results in changes primarily in the low-frequency dynamic modes, but in the lateral-directional axes, changes in N'_v and L'_v affect not only low-frequency modes, such as the spiral, but also higher frequency modes, such as the Dutch roll. In terms of the characteristics that affect flying qualities, one may say qualitatively that if the lateral and directional gradients are changed by varying these derivatives then changes to either gradient will alter the location of the spiral root, changes to the lateral gradient will in addition have a strong effect on the amount of Dutch roll excitation in the roll response through the parameter $|\phi/\beta|_d$, and changes to the directional gradient will have strong influences on both $|\phi/\beta|_d$ and the frequency of the Dutch roll (ω_d).

The Airworthiness Criteria require that both the lateral and directional gradients be stable (right stick and left pedal for right sideslip) on both sides of trim. As with the longitudinal gradient, an obvious variation is to examine a neutral gradient in addition to a stable gradient for each axis. For the directional gradient, however, a neutral gradient implies effectively no directional stiffness and, concomitantly, a Dutch roll frequency approaching zero, which has been shown consistently to be inadequate for instrument approach in STOL work (e.g., ref. 17); preliminary checkout runs in the simulator confirmed that such a configuration was unacceptable. It was further reasoned that tail-rotor-failure considerations lead to the design of some aerodynamic directional stiffness in forward flight in all modern helicopters. On these bases, the baseline directional gradient, corresponding to a fairly stiff ($\omega_d \simeq 2.0$ rad/sec) directional axis, and a reduced but still stable gradient were designed.

Appendix A lists the feedback gains of lateral velocity (sideslip) to lateral and directional controls. Note that no scheduling with speed was used: the characteristics of the baseline configuration are almost invariant with speed in the range of interest (50-80 knots). Note also that the feedback to the lateral control is less destabilizing for configurations S06 and S08 than it is for S03 and S04: the reduced directional stiffness of S06 and S08 necessitated some remaining effective dihedral effect to maintain all the characteristic roots within the dynamic criteria. Also recall that configurations S01-S08 are with a control-force/displacement relationship determined by the feel system, while for configurations S13-S18 the force gradients and breakouts are zero.

Using the feedback gains discussed above, plus the baseline hingeless-rotor configuration characteristics, the eight force-ON and six force-OFF static gradient configurations are listed in table 2 by the actual gradients examined.

TABLE 2.- STATIC GRADIENT CONFIGURATIONS

Configuration	δ_{ES}/V, in./20 knots	δ_{AS}/β, in./15°	δ_{RP}/β, in./15°
S01(S13)	-0.64	0.57	-0.72
S02(S14)	-0.01	0.57	-0.72
S03(S15)	-0.64	-0.01	-0.71
S04(S16)	-0.01	-0.01	-0.71
S05(S17)	-0.64	0.57	-0.19
S06(S18)	-0.64	0.03	-0.18
S07	-0.01	0.57	-0.19
S08	-0.01	0.03	-0.18

The achieved characteristic roots for these configurations at 60 knots, level flight, are summarized in appendix A. As was mentioned earlier, the design intent for this group of configurations was to vary the static stability while maintaining dynamic stability within the levels called out in the Airworthiness Criteria. The criteria of interest are those normal category single-pilot and all transport category operations, and are taken essentially from MIL-H-8501A (ref. 5), being given in terms of damped frequency period (P_D) and cycles to half amplitude ($C_{1/2}$) or time-to-double-amplitude (T_D):

1. For $P_D \leq 5$ sec, $C_{1/2} \leq 1$
2. For $5 < P_D \leq 10$ sec, $C_{1/2} < 2$
3. For $10 < P_D \leq 20$ sec, must be damped
4. For $P_D > 20$ sec, $T_D \geq 20$ sec
5. Unstable aperiodic response should not be objectionable

In comparing the characteristic roots given for configurations S01-S08, S13-S18 as given in appendix A, it may be seen that these criteria are essentially met by all of the configurations. The low-frequency characteristics that are of interest are summarized in table 3.

TABLE 3.- STATIC GRADIENT CONFIGURATION DYNAMIC CHARACTERISTICS

Configuration	Characteristics
S01, S13	$P_D \doteq 19$ sec; barely damped; no unstable aperiodic
S02, S14	$P_D \doteq 96$ sec; barely damped; no unstable aperiodic
S03, S15	$P_D \doteq 19$ sec; barely damped; no unstable aperiodic
S04, S16	$P_D \doteq 104$ sec; well damped; unstable aperiodic, $T_D \doteq 2{,}000$ sec
S05, S17	$P_D \doteq 19.6$ sec; well damped
	$P_D \doteq 19$ sec; $T_D \doteq 330$ sec
S06, S18	$P_D \doteq 19.4$ sec; $T_D \doteq 175$ sec
S07	$P_D = 22$ sec; well damped
	$P_D = 71$ sec; damped
S08	$P_D = 60$ sec; $T_D = 40$ sec

Note that configurations S01, S03, S05, and S06 do not quite meet the criteria, but the difference between a 19-sec and a 20-sec period is academic — for times of roughly 1 min, these configurations will appear to have neutrally damped, low-frequency oscillations. The "unstable" aperiodic root of configuration S04 is also, for practical purposes, a root at the origin, and should fall within any "nonobjectionable" criterion. Effectively, therefore, all of these configurations satisfy the dynamic criteria.

It is emphasized again that the design intent of these configurations is to examine the influence of static stability in the manner that it is prescribed in the Airworthiness Criteria, meeting other characteristic requirements as presented in that document. These criteria do not specifically address "classical" flying-qualities parameters, such as Dutch roll frequency or roll-to-sideslip ratio, and so values of such parameters vary among the configurations. For example, the Dutch roll frequency and damping ratio are relatively constant ($\omega_n \doteq 2.0$, $\zeta \doteq 0.7$) among the configurations with the higher directional control gradient (S01-S04, S13-S16), but they vary with lateral gradient for the lower directional gradient cases (S05-S08, S17-S20). The object of the configurations as designed is to determine the suitability of a variety of helicopter characteristics for IFR through considerations of those that are measured and prescribed in the fairly general way given by the Airworthiness Criteria.

One other aspect of these configurations as designed should be noted. Classical flying-qualities investigations tend to examine the influence of one variable while maintaining remaining parameters at "good" values. In this experiment, it was desired to consider the static gradients in both the classical manner and in a manner that combined "bad" values. Hence, configurations S02(S14), S03(S15), and S05(S17) consider one axis with a reduced gradient, but configurations S04(S16), S06(S18), S07, and S08 consider two or three axes with reduced gradients. The intent is to ascertain the extent of further change in pilot rating by having more than one item fail to meet the criteria.

Finally, as has been discussed, the question of control-force versus control-position gradients was examined in a preliminary way by considering the eight sets of hingeless static gradient dynamics with both a prescribed control-force-displacement relationship provided by a feel system and with the force-feel OFF (no forces with displacement). For configurations S01-S08, the force-feel characteristics were selected to be:

TABLE 4.- FORCE-FEEL CHARACTERISTICS FOR CONFIGURATIONS S01-S08

	Gradient, lb/in.	Breakout, lb/in.	Travel, in.
Pitch	0.5	0.5	±6.0
Roll	0.5	0.5	±6.0
Directional	3.0	1.5	±3.25
Collective	0.0	Adjustable	10.0

The pitch-roll force gradients are one half those used in the previous experiment and were selected to correspond to the minimum requirement in MIL-F-83300 (ref. 9). For configurations S13-S18 with the force-feel OFF, both the gradient and the breakout forces were zero. This mechanization implies a pure "limp stick" — the controller will not stay where the pilot puts it unless he holds on to it. A preferable, and more realistic, implementation would have been to maintain the breakout forces as in table 4 but to have zero force-displacement gradients; it was not possible to consider this implementation in this experiment.

It should also be noted that with force-feel ON, two types of trimming capability were available to the pilot. One, which was that used in the previous experiment (ref. 6), is a simulation of a magnetic brake device: a push button deactivated all forces in all three axes until the pilot released it. The other means for retrimming was through constant rate trimmers in all three axes ("top hat" two-axis button on the cyclic control for pitch-roll, slew switch on the collective for yaw); the trim in all three axes was 0.5 in./sec. Both methods of trimming were available for all force-ON configurations.

Augmentation Configurations

The second main purpose of this experiment was to examine the usefulness of several levels of stability-control augmentation, given baseline aircraft minimum levels of static stability. For the hingeless-rotor configurations, the baseline for this part of the investigation is configuration S08, which has a rate-damping-input-decoupling SCAS with, as we have seen, the minimum static gradients designed for investigation. To extend the SCAS investigation to rotor types different from the hingeless configuration, it is necessary to provide baseline configurations for articulated and teetering rotor types that have similar SCAS and minimum static characteristics.

Toward this end, a teetering and an articulated rotor configuration from the previous experiment (ref. 6) were selected to provide these baselines for this experiment. Some of the aerodynamic and geometric design parameters for these configurations are given in appendix A. For each rotor type, it was desired to have a baseline configuration with SCAS and static gradient characteristics similar to the hingeless configuration S08; they are designated S10 for the teetering rotor and S12 for the articulated rotor. In addition, as a spot comparison on the static gradient configurations for the hingeless rotor described above, it was decided to design one additional teetering and articulated configuration to have stable longitudinal and lateral gradients, but a reduced directional gradient for comparison with S05; these configurations are designated S09 for the teetering and S11 for the articulated rotors, respectively.

The same procedures used to determine Δ_{AS}/u, Δ_{AS}/v, and Δ_{RP}/v (which were described above) were used to determine these gains for the teetering- and articulated-rotor configurations. It should be noted that because of the scheduling with speed of the input decoupling gain of longitudinal control to collective stick inputs, it was necessary to add stabilizing Δ_{ES}/u feedback for both configurations to achieve a neutral longitudinal gradient; in the previous experiment, the longitudinal gradients for both rotor configurations with a rate-damping-plus-input-decoupling SCAS were unstable at 60 knots (ref. 6). In addition, more rate damping (Δ_{ES}/q and Δ_{AS}/p) was used in this experiment than in the previous one to obtain effective augmented values of Mq and L'_p that were the same as the hingeless configurations. The gains for these four configurations are given in appendix A.

The designed static gradients at 60 knots are summarized in table 5.

TABLE 5.- TEETERING- AND ARTICULATED-ROTOR CONFIGURATION CONTROL POSITION GRADIENTS

Configuration	δ_{ES}/V = 20 knots	δ_{AS}/β = 15°	δ_{RP}/β = 15°
S09	-0.64	0.52	-0.33
S10	-0.02	0.02	-0.34
S11	-0.48	0.66	-0.20
S12	+0.01	0.18	-0.20

As can be seen, for the teetering configurations (S09, S10) the pitch/roll gradients are similar to those for the hingeless configurations (S05 and S08, respectively), although the directional gradient is higher; the reason is lower values of control sensitivity for the teetering configuration, for both $-L'_v$ and N'_v are actually somewhat lower than for the hingeless cases. As can be seen from the tabulation of the characteristic roots given in appendix A, these teetering configurations also meet all of the dynamic criteria. For the articulated-rotor configurations, it can be seen that a neutral lateral gradient could not be achieved for configuration S12 without driving the spiral root unstable: the aperiodic root that resulted from the design value given in table 5 gave a time-to-double-amplitude of 16 sec, and attempting to reduce the gradient further made this situation even worse.

It turned out, in fact, that configuration S12 was unflyable for a reason that was not apparent during the configuration design process. Because of the selection of the geometric locations (and sizes) of the vertical fin and tail rotor for the articulated-rotor configuration, the tail fin stalled at positive sideslip angles, thereby drastically reducing directional stiffness. For configuration S12, the already slightly unstable characteristics at zero sideslip became a rapid divergence because of this characteristic. The influence of it on S11 can be seen in the directional stiffness derivative:

$$N'_v = 0.035 \quad , \beta = 0$$

$$N'_v = 0.036 \quad , \beta = -15°$$

$$N'_v = -0.013 \quad , \beta = +15°$$

At +15°, the negative stiffness contributes an unstable oscillation of period 21 sec, but a time-to-double of 6 sec. Because of these unusual directional characteristics, which were not evident until the evaluation portion of the experiment began, the results obtained with configuration S11 (and to some extent with S29, S30, and S31 — to be discussed) should not be considered as generally representative of an articulated-rotor system.

Starting with those configurations having the lower level of static stability in each axis, the following four types of SCAS were selected to be designed for implementation:

1. Rate damping pitch/roll/yaw plus input decoupling (the baseline configurations described above: S08, S10, S12).

2. Number (1) plus turn-following enhancement through directional augmentation (TDA: S21, S26, S29).

3. Number (2) plus attitude feedback in pitch/roll to achieve pitch and roll attitude command (AC: S24, S27, S30).

4. Number (3) plus proportional-plus-integral prefilters in pitch/roll to achieve pitch and roll rate-command-attitude-hold (RCAH: S25, S28, S31).

These four levels of SCAS were designed for the three rotor configurations discussed above to provide continuity with the previous experiment.

The reasons for selecting these levels of SCAS design were as follows. The baseline rate-damping-plus-input-decoupling requires only angular rate sensors and is compatible with the limited-authority, series servo actuators that are typical of most current helicopter practice; input decoupling plus high rate damping levels were used to ascertain the IFR capability of aircraft with low static stability in all axes, given the simplest type of SCAS that might be considered. Turn-following augmentation to relieve the poor directional statics is the next obvious choice, because the pilot can be relieved of the directional control tasks (e.g., turn coordination, sideslip suppression). For single-rotor helicopters, either (1) a sizeable vertical fin plus additional yaw rate damping and roll-to-directional control interconnects or (2) possibly, sideslip feedback directionally, as is used in some tandem rotor helicopters, is required. As a result, perhaps some level of complexity above that of rate-damping augmentation is inferred. Finally, the addition of attitude feedback in pitch and roll, implemented either as attitude command or rate command with attitude retention, represents a modest increase in complexity because of the need for attitude sensors. In the previous experiment, attitude command augmentation was required to achieve a satisfactory IFR nonprecision-approach capability for the configurations investigated (ref. 6); in fact, studies have demonstrated the possibility of performing precision decelerating approaches with this type of augmentation and with suitable displays (ref. 18). With limited-authority actuators, however, a rate-command-attitude-hold implementation may be required (e.g., ref. 19), and so the influence of this mechanization, which was not investigated in the previous experiment, needs to be ascertained.

The design of the rate-damping-plus-input-decoupling augmentation for each of the three rotor types was discussed earlier in this section. The baseline configuration to examine the influence of type of augmentation was selected as the one with minimum static stability; hence, the baseline hingeless configuration for this portion of the experiment is S08, the baseline teetering is S10, and the baseline articulated is S12. It is emphasized that the design parameters (geometry and feedback/feed-forward) of these configurations remain the same for the higher level SCAS designs; hence, only the additions or modifications will be described.

For the turn-following augmentation configurations, the modifications consist of stabilizing feedback of lateral velocity (sideslip) to the directional control, additional yaw rate damping feedback, and a roll-to-directional control interconnect (hingeless configuration only). Because the side-force-to-sideslip characteristics of the helicopter configurations considered are quite low ($Y_v \doteq -0.1$ for hingeless, $Y_v \doteq -0.08$ for teetering, $Y_v \doteq -0.06$ for articulated), it was hypothesized that the pilot would not have a large lateral acceleration cue to assist him in minimizing sideslip, and so the primary purpose of the turn-following directional augmentation (TDA) is to reduce sideslip caused by roll control inputs and concomitantly to minimize the Dutch roll component in the roll response. Toward this end, directional augmentation to achieve a Dutch roll frequency of about 2.5 rad/sec was incorporated, along with additional yaw damping to keep this oscillation well damped ($\zeta > 0.7$). By increasing the Dutch roll frequency with augmented directional stiffness, the roll-to-sideslip ratio was also reduced. In addition, for the hingeless configuration, a small roll-to-yaw control interconnect was introduced to reduce the frequency of the zero in the roll response and attempt to place it approximately on the Dutch roll pole; such an interconnect was not considered necessary for either the teetering or articulated configurations. Considering the high level of Dutch roll damping and near pole-zero cancellation of the hingeless configuration without the interconnect, the roll-to-yaw interconnect likely was not necessary for that configuration. The changes in gains going from the baseline rate-damping to the turn-following configurations for the three rotor types, as well as the achieved dynamics, are summarized in appendix A. It will be noted that the directional stiffness of the articulated case was again assumed to be constant with sideslip; hence, insufficient augmentation to alleviate the decrease of N'_v with positive sideslip was used.

The attitude command SCAS added simply pitch and roll attitude feedback to the pitch and roll channels, respectively. Attitude feedbacks sufficient to give effective values of M_θ and L_ϕ equal to -6.25 were used; this level corresponds to an undamped natural frequency of about 2.5 rad/sec. Although it may not be necessary to use this much attitude augmentation (ref. 18), this level was selected to be consistent with the hingeless-rotor attitude command configuration of the previous experiment (ref. 6) as well as to maximize the amount of turbulence proofing afforded by attitude augmentation. In the previous experiment the attitude augmented dynamics varied among the rotor types; in this experiment, the level of feedback was varied among the rotor types to achieve the same augmented dynamics of approximately 2.5 rad/sec for all three rotor types. For the teetering-rotor configuration, therefore, quite high gains were required; they would probably not be compatible with a limited-authority servo implementation. The gains used are summarized in appendix A.

The final SCAS is a rate-command-attitude-hold (RCAH) system in pitch and roll, which, in this experiment, was implemented with proportional-plus-integral prefilters on the pitch and roll control inputs feeding into the attitude command system described above. In general, an RCAH SCAS can be implemented in several ways to be consistent with a limited-authority series servo mechanization. The prefilter mechanization was selected because of the structure of the simulation model shown in figure 1; alternative methods involve, for example, switching the attitude feedback in or out as a function of the force applied at the controller by the pilot (e.g., ref. 19). With the prefilter method selected, the design parameters are the ratio of proportional-to-integral input and the size of the dead-band required to avoid constant integration of unwanted inputs.

The proportional/integral ratio was selected to provide a zero that nearly cancels one of the attitude roots provided by the attitude stabilization. In simple terms, the attitude transfer function is

$$\theta/\delta_{ES} \doteq \underbrace{\left(K_1 + \frac{K_2}{S}\right)}_{\text{prefilter}} \underbrace{\left(\frac{K}{S^2 + 2\zeta w_n S + w_n^2}\right)}_{\text{attitude stabilized response}} \tag{13}$$

$$= K_1\left(\frac{S + K_2/K_1}{S}\right)\left(\frac{K}{S^2 + 2\zeta w_n S + w_n^2}\right) \tag{14}$$

$$= K_1\left(\frac{S + K_2/K_1}{S}\right)\left(\frac{K}{(S + \lambda_1)(S + \lambda_2)}\right) \tag{15}$$

for an overdamped attitude system.

Then, if $K_1/K_2 \doteq \lambda_1$ (the smaller root), the transfer function becomes

$$\theta/\delta_{ES} \doteq \frac{K_1}{S}\frac{K}{S + \lambda_2} \tag{16}$$

The ratios were selected in this manner to give time constants for the pitch response of about 0.2 sec and for the roll response of about 0.1 sec, both of which are similar to the rate-damping augmentation system time constants. For pitch, a ratio of 1.27 was used for all three rotor types; and for roll a value of 0.67 was used for all three. The resulting transfer functions are summarized in appendix A. The input to the integrators included a ±0.1-in. deadzone on control position to avoid constant integration of small inputs. Because control position rather than force was used for the deadzone, it was necessary to "float" the deadzone position as a function of computed trim stick position so that different trims would not exceed the limits; the same result could have been achieved by tripping the integrators above a prescribed level of force of the controllers. This type of implementation means that use of the "beeper" rate trim did not trip the integrator (as it would not if force were used) and so the trimmer was effectively an attitude command rather than rate command.

Turbulence Model (All Configurations)

A third major variable in the experiment was the influence of external disturbances on the suitability for the task of the evaluation configurations that were described above. In the previous Ames experiment, no disturbances due to atmospheric turbulence were included (ref. 6), partially because of the lack of a good model for helicopter applications. Since winds and turbulence are an important factor in IFR terminal-area operations, however, an initial exploratory examination using a simple model for external disturbances was considered necessary in this experiment, if only to indicate trends of sensitivity to such disturbances. It is emphasized that the intent is to indicate the influence of some sort of external aerodynamic disturbance on the terminal-area flying qualities rather than to provide a validated realistic set of responses of the helicopter configurations to atmospheric turbulence.

The simple model for atmospheric turbulence was taken from reference 20, which in turn is a simplification of the model proposed in reference 21. The model as used here provides three linear turbulence components defined in a wind axis system (u_g, v_g, w_g); the three rotational components (p_g, q_g, r_g) typically used to approximate the first gradient were neglected. The three components are based on a Dryden spectrum, with intensities determined either as constants or as a fraction of an assumed wind speed. Provision for a wind velocity at a prescribed direction is included as is provision for a wind shear between 20 and 200 ft. These aspects were not used for this experiment, and the wind velocity was selected to be zero. Scale lengths were 1,000 ft for the longitudinal and lateral components and for the current altitude for the vertical component; again, although a provision for variations in scale length for altitudes below 200 ft is given in reference 20, this option was not exercised in this experiment. In reference 20, the break frequencies of the Dryden spectra are determined by the ratio of the wind speed to the scale length, but in this experiment the velocity of the aircraft relative to the air mass was used since hover was not included in the task; hence, break frequencies for the longitudinal and lateral spectra were approximately

0.1 rad/sec, and for the vertical spectrum they ranged from 0.06 rad/sec to 0.17 rad/sec, depending on altitude. To avoid compromising the results with an unrealistically high level of turbulence, the intensities were selected at a low level to represent light turbulence: $\sigma u_g = \sigma v_g = 1.5$ ft/sec and $\sigma w_g = 3.0$ ft/sec.

The influence of this level of turbulence, modeled in this way, was examined by conducting each evaluation with one approach in no turbulence and one approach in the turbulence just described. It is emphasized again that the intent was to obtain a preliminary idea of the sensitivity of the various configurations, in terms of task performance and pilot control usage, to external disturbances; the turbulence model used is not intended to be considered as a validated representation of the actual terminal-area situation.

Summary of Configurations

The configurations that have been described are summarized in the configuration test matrix given in table 6. Each configuration was evaluated with and without turbulence created by the model described above. Appendix A provides summaries of the dynamic characteristics and the stability-control derivatives of the configurations as evaluated.

TABLE 6.- DESIGNED CONFIGURATION — SUMMARY

Unaugmented aircraft static gradients (a)			Level of SCAS (b)	Configuration number			
Long.	Lat.	Dir.		Hingeless, forces-ON	Hingeless, forces-OFF	Teetering, forces-ON	Articulated, forces-ON
S	S	S1	RDID	S01	S13		
N	S	S1	RDID	S02	S14		
S	N	S1	RDID	S03	S15		
N	N	S1	RDID	S04	S16		
S	S	S2	RDID	S05	S17	S09	S11
S	N	S2	RDID	S06	S18		
N	S	S2	RDID	S07	S19		
N	N	S2	RDID	S08	S20	S10	S12
N	N	S2	TDA	S21		S26	S29
N	N	S2	AC	S24		S27	S30
N	N	S2	RCAH	S25		S28	S31

(a) S = stable; N = approximately neutral; S1,S2 = two levels of stable.
(b) RDID = rate damping plus input decoupling; TDA = RDID plus turn-following directional augmentation; AC = TDA plus pitch-roll attitude command augmentation; RCAH = AC plus pitch-roll prefilters to give rate command, attitude hold augmentation.

CONDUCT OF EXPERIMENT

Simulator Apparatus

The simulation experiment described in this report was carried out at Ames Research Center using the Flight Simulator for Advanced Aircraft (FSAA) (fig. 2) and a Redifon visual display system. The motion system of the simulator is a six-degree-of-freedom device designed to impart rotational and translational movement to the cockpit. A detailed description is given in reference 22 and in appendix B of this report.

For this experiment, the right seat of the cockpit was fitted with conventional helicopter flight controls and a basic set of flight instruments (fig. 3). A sideslip instrument was provided during the configuration checkout phase, but was covered for the later evaluation phase. A large ADI provided heading data in addition to pitch and roll, but a flight-director mode was not available. Turn-slip data were shown on a separate instrument, as is typical of helicopter display presentations (fig. 3); the remaining flight and navigation instruments were conventional and arranged in the usual "T" presentation. The collective stick was provided with friction control, but had zero force-displacement gradient. The force-feel characteristics of the cyclic stick and directional pedals were provided by an electrohydraulic unit with adjustable breakout, static gradient, viscous damping, and friction. The force-feel characteristics and control travels for the helicopter configurations are as described in the experiment design section (table 4).

The Redifon visual system camera operated over a model of the landing area and surrounding terrain. The total field of view encompassed 36° vertically and 48° horizontally. The visual scene was displayed through the forward cab window on a color TV monitor with a collimating lens. The display was only used during periods when the pilots were conducting familiarization runs with a configuration. Evaluation runs were conducted with a faded gray monitor to simulate flight in the clouds (IMC). The task was designed to always include a missed-approach segment after reaching the minimum descent altitude (MDA) and, therefore, did not include a transition from IMC to VMC.

Test Procedure

The situation simulated was the normal operation of a normal category helicopter in the terminal area under instrument meteorological conditions (IMC). Simulated approaches were made with reference to a conventional set of flight and navigation instruments and in accordance with a specific nonprecision instrument approach procedure. The very high frequency omnidirectional range (VOR) instrument approach chart that was used is shown in figure 4.

The primary task was to fly the VOR approach and execute a missed-approach procedure while manually controlling the aircraft and maintaining flight variables to within acceptable tolerances. There were no ancillary tasks,

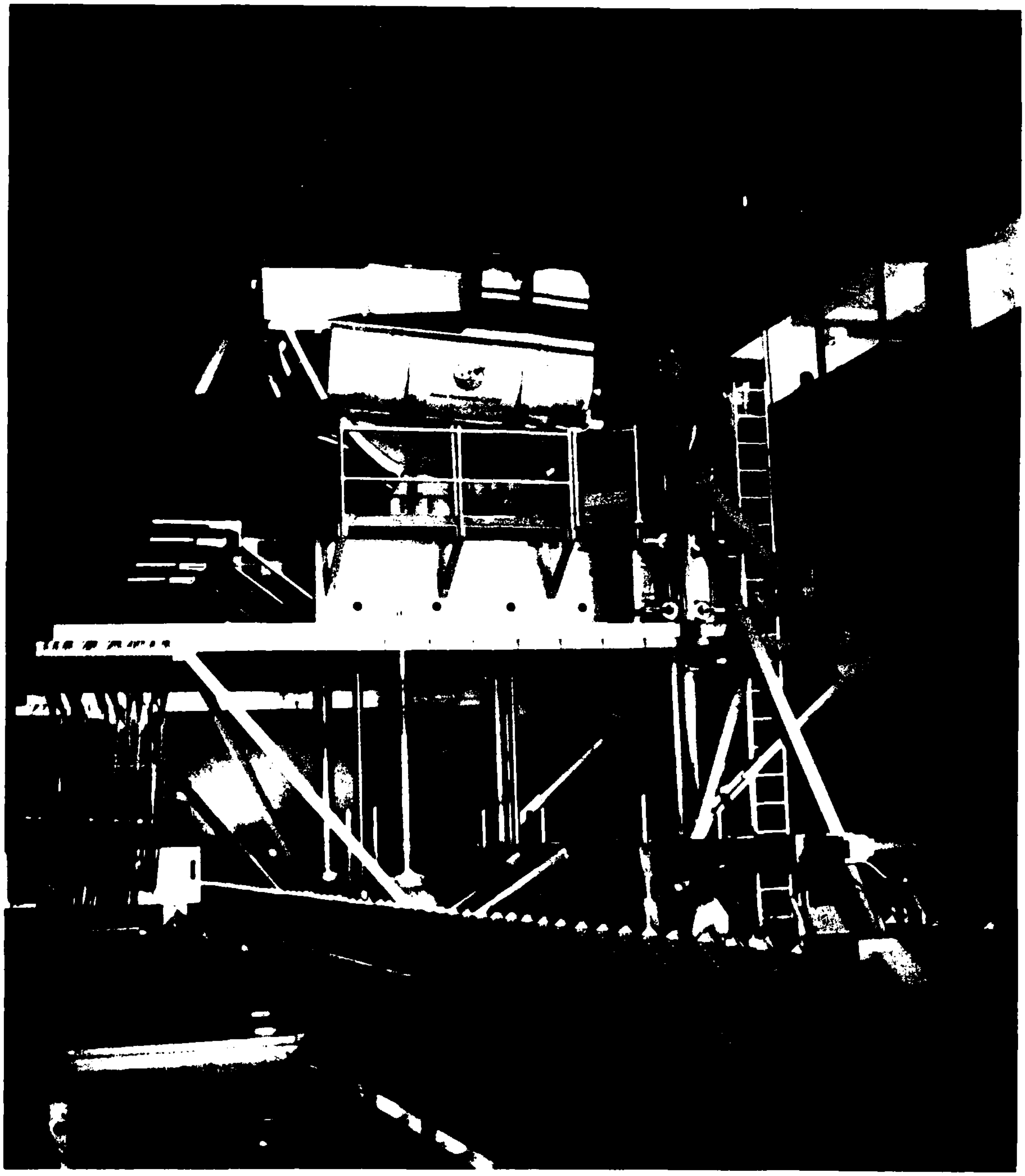


Figure 2.- Flight simulator for advanced aircraft.

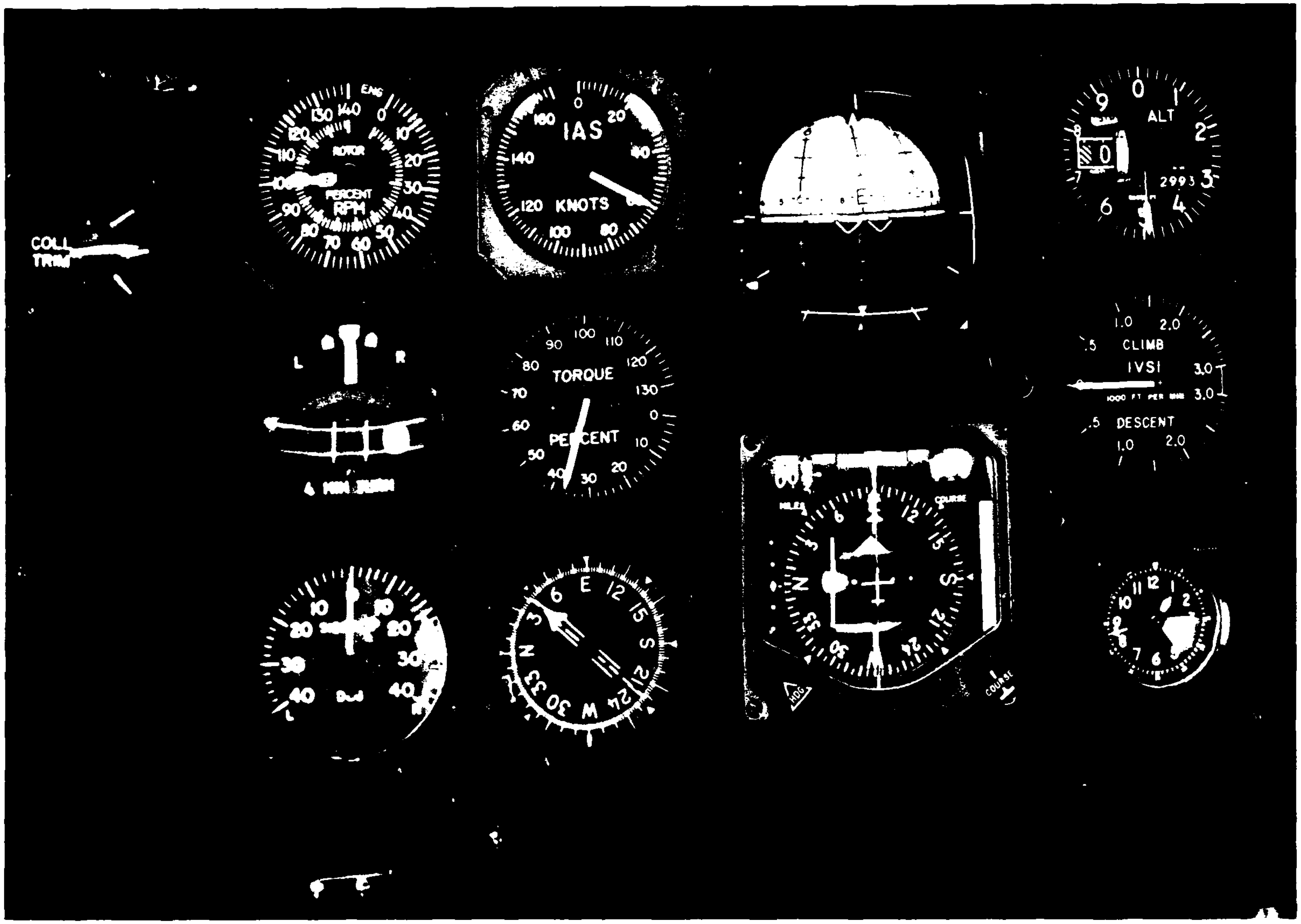


Figure 3.- Instrument panel.

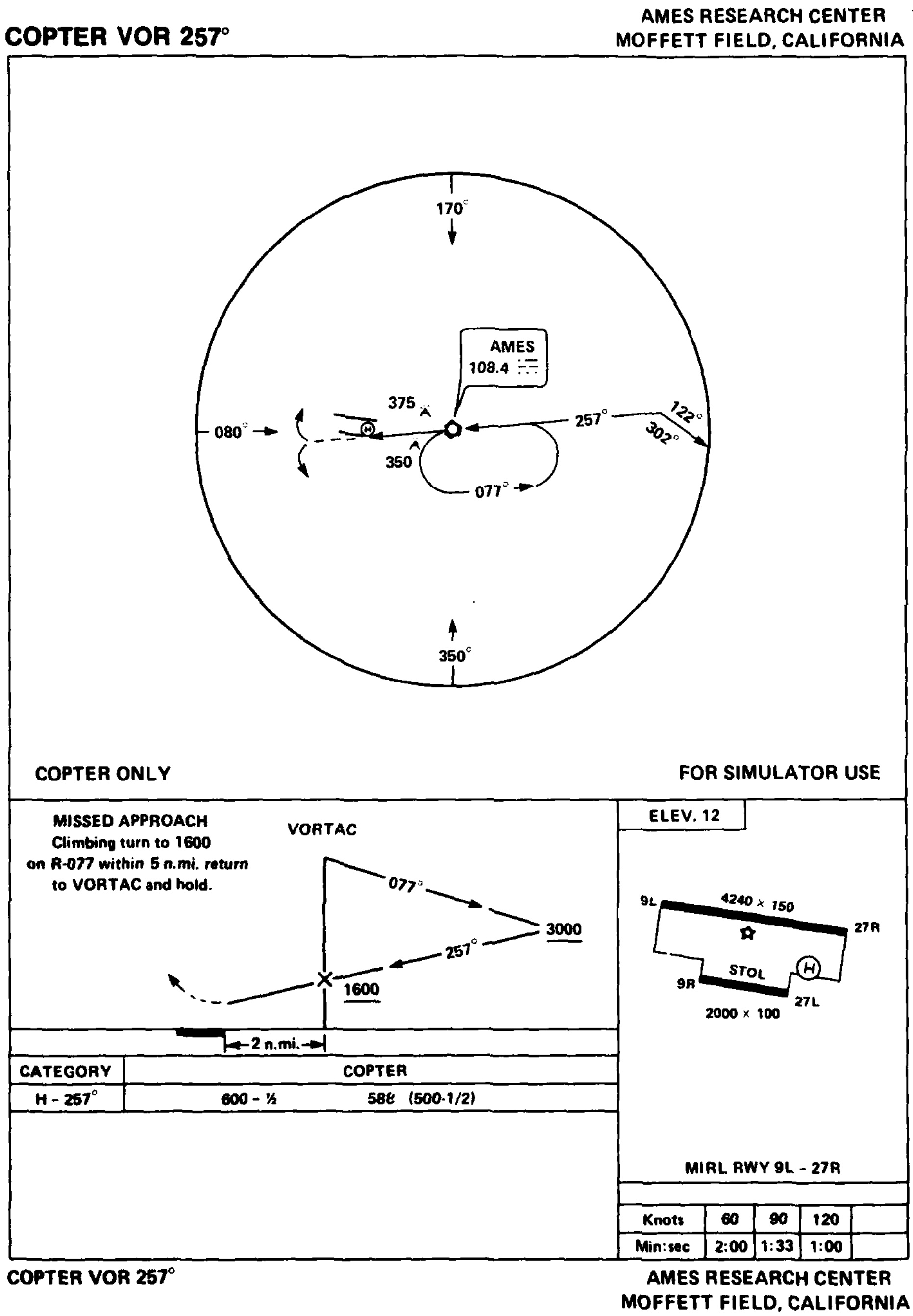


Figure 4.- VOR approach plate.

such as chart handling, radio frequency selection or air-to-ground communication. Therefore, there were no duties that under other conditions might have been assigned to other crew members, and the simulator was occupied solely by the evaluation pilot. With the exception of alternating the direction of the missed-approach turn, all of the approaches followed the same procedure. The procedure consisted of the following elements (see fig. 5):

1. Initial conditions at an altitude of 1,600 ft MSL (height above the heliport of 1,588 ft), 80-knot airspeed, and displaced to the left of the inbound 077° radial, heading 257°.

2. Standard rate turn at 1,600 ft to an intercept heading of 287° at 80 knots.

3. Intercept and track inbound on 077° radial (257° course), decelerate to 60-knot approach speed.

4. Identify station, start timing 75 sec, transition to 1,000 ft/min descent holding 60 knots.

5. Track outbound 257° radial while holding 60 knots and 1,000 ft/min descent.

6. Transition to level flight at an altitude of 600 ft MSL, continue at 60 knots and 600 ft until completion of 75-sec period.

7. Execute missed-approach procedure, standard rate turn alternating the direction of the turn from one approach to the next, climb to 1,600 ft; tracking inbound back to the station was not included.

The pilots were allowed time to initially evaluate each configuration under VMC conditions without being constrained to fly the specific task. During this period, the pilots could familiarize themselves with the overall handling qualities of each configuration and thus gain a feel for the response to various control inputs and an initial impression of pilot workload. They were then instructed to conduct two VOR approaches, one without turbulence and one with turbulence, and to evaluate each configuration as if it was an aircraft presented for certification in normal operation in IMC.

The configurations are divided into three main groups as follows: (1) static gradient configurations, force-feel ON; (2) static gradient configurations, force-feel OFF; and (3) augmentation-type configurations. The evaluation sessions were planned to include at least one configuration from each group, in order to minimize any bias caused by evaluating a series of all good or all bad configurations.

In summary, each evaluation consisted of a familiarization run in VMC and two VOR approaches in IMC. The first approach was without turbulence followed by an approach with turbulence. At the conclusion of the first approach, the pilots assigned a Cooper-Harper pilot rating and made comments with reference to the Comment Card (table 7). At the conclusion of the

VOR APPROACH TASK

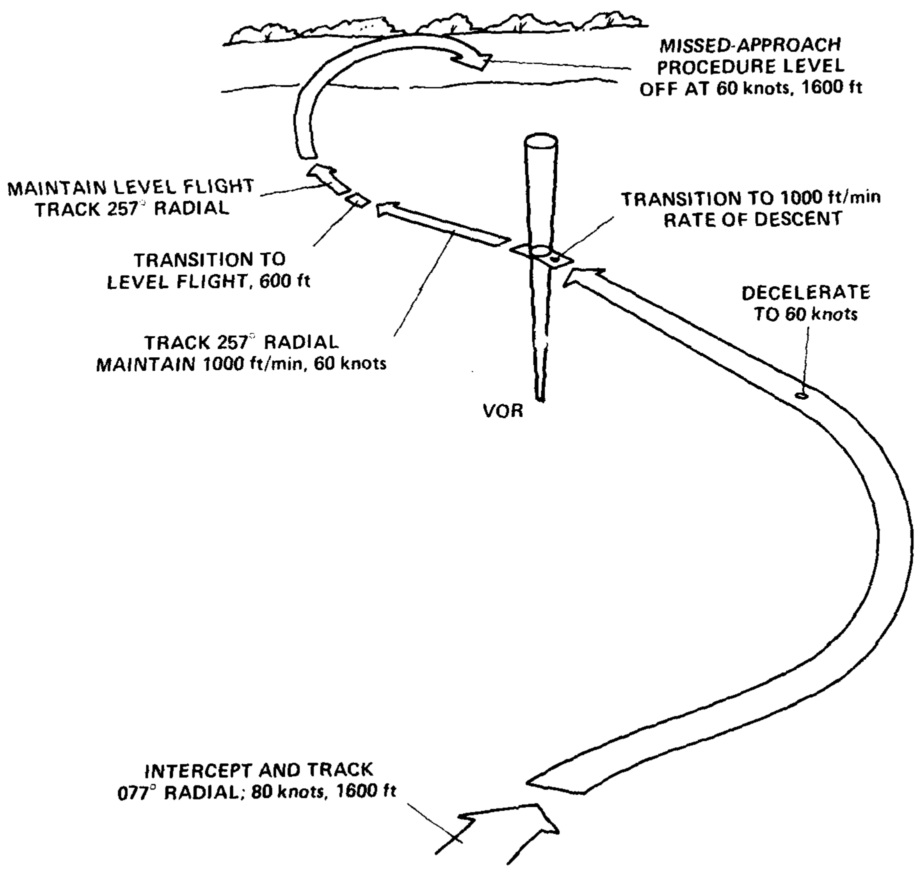


Figure 5.- VOR approach task elements.

TABLE 7.- PILOT COMMENT CARD

Summary comments		
(Turb)[a]	1.	Good features
(Turb)	2.	Objectionable features
(Turb)	3.	Pilot rating (C-H)
		a. Record dichotomous decision making process, adjectives best suited
		b. Identify deficiency most influencing rating
Specific comments		
(Turb)	1.	Ability to trim
		a. Longitudinal
		b. Lateral/directional
	2.	Response to inputs required to perform task
		a. Pitch: initial response, predictability of final response, sensitivity
		b. Roll: initial response, predictability of final response, sensitivity
(Turb)		c. Speed control: precision, predictability
(Turb)		d. Turn coordination: requirements in context of task
		e. Thrust control: Satisfactory? Coupling to other axes?
(Turb)	3.	Task performance
		a. Deceleration and VOR acquisition
		b. VOR tracking
		c. Descent to 600 ft
		d. Missed-approach maneuver
	4.	Any special control techniques required?
(Turb)	5.	Effects of turbulence/wind
		a. Which axes?
		b. Identify problem with turbulence (if any)
Final comments		
	1.	Any change to assigned pilot rating as result of comments?
	2.	Any simulation deficiencies?

[a](Turb) indicates comments requested after second IMC approach in turbulence.

second approach, the pilots assigned an overall Cooper-Harper rating to the configuration in the context of helicopter IMC operations including the influence of turbulence and commented on those particular characteristics that were influenced by turbulence (table 7).

Evaluation Pilots

Four test pilots participated in the experiment. Pilot G, a NASA research pilot, has extensive experience in V/STOL and conventional airplanes and has 1,100 hr in rotary wing aircraft, 50 hr of which is instrument time. Pilot H, an Army test pilot, has extensive military test experience — 2,300 hr in rotary wing aircraft and 100 hr of rotary wing instrument time. Pilot K, an FAA test pilot, has civil certification test experience; he has 3,000 hr in rotary wing aircraft and 82 hr of rotary wing instrument time. Pilot M has 295 hr in rotary wing aircraft, 5 hr of which is instrument time. Pilot M is a test pilot at the Flight Research Laboratory, National Aeronautical Establishment, Canada.

Evaluation Data

A total of 105 evaluations (210 VOR approaches) were made by the four pilots. The average time for completing the approach, including the missed-approach segment, was 4 min and 22 sec. Five categories of data were recorded: (1) numeric pilot ratings based on the Cooper-Harper scale (ref. 23); (2) pilot comments recorded during the approach and following the approach, using the pilot comment card as a guide; (3) pilot control usage determined from time histories of the primary flight control positions; (4) pilot-vehicle performance determined from time histories of the aircraft state and flight variables; and (5) pilot-simulator environment determined from time histories of the simulator input command and feedback variables. Variables were recorded on strip charts to permit observation while tests were in progress and on digital tape (sampled at 10 times per second) for subsequent analysis. The recorded variables included: helicopter body attitudes; helicopter angular and linear rates and accelerations; helicopter flightpath coordinates; VOR radial tracking error; turbulence components; pilot control positions; SCAS actuator positions; and simulator input command and feedback signals.

FLYING-QUALITIES RESULTS

In this section the flying-qualities results, in terms of pilot ratings and pilot comments, are presented and discussed. Because of the fairly large quantity of data obtained (somewhat over 200 pilot ratings), the discussion is broken down into several groups emphasizing the influences of several factors. Accordingly, the following subsections discuss (1) the static gradient configurations with force-feel ON; (2) the static gradient configurations with force-feel OFF; (3) the configurations aimed at examining different types of augmentation; (4) the effects of turbulence; and (5) the differences or similarities among the pilots.

Static Combined Force and Position Gradient Configurations

The influence of combined static control position and force gradients on helicopter IFR flying qualities may be examined by considering the eight hingeless-rotor configurations that included nonzero force feel characteristics (S01-S08). A brief summary of the evaluations of each configuration is given in the following paragraphs (see appendix C for complete pilot comments), followed by a discussion of inferences that can be drawn concerning the influence of the static gradients singly and in combination. It is emphasized again that these inferences are predicated on the other characteristics of these configurations: high rate damping in pitch/roll, input coupling reduction, high control sensitivities, and characteristic roots that meet the dynamic requirements of the Airworthiness Criteria. Note that gradients are calculated from the six-degree-of-freedom equations of motion using small perturbation derivatives at 60-knot level flight trim.

S01: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.72 in./15° — This baseline configuration with stable control position gradients in all axes was effectively a repeat of a hingeless-rotor configuration examined in the previous experiment (ref. 6). The average pilot rating without turbulence was 4.3, with a range of ratings from 4.0 to 4.5 (seven evaluations); the average pilot rating with turbulence was 5.3, with a range of ratings from 4.5 to 7.0 (seven evaluations). Without turbulence, the ratings agree exactly with those from the previous experiment (i.e., 4 and 4.5). According to pilot comments the good features of this configuration in smooth air were (1) decoupled responses to control inputs, (2) good pitch and roll response — although roll was apparently a bit too sensitive — with good trimmability in these axes, and (3) good speed control. The major objectionable feature that prevented a rating of satisfactory (PR < 3½) in smooth air was the need to pay constant attention to pitch and roll attitude plus some problems with roll sensitivity (inadvertent roll excursions, overbanking in turns, unsteady turn rates). Pilot G, in particular, indicated that the very nature of the VOR task would require attitude stabilization assistance for the single-pilot situation. The influence of turbulence on the flying qualities was quite high, with control of airspeed and turn rate during the missed approach being degraded considerably.

S02: δ_{ES}/V = -0.01 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.72 in./15° — This configuration has modified longitudinal velocity perturbation derivatives (primarily M_u) to achieve a neutral longitudinal stick position gradient; the remaining characteristics are identical to S01. The average pilot rating without turbulence was 4.8 (seven evaluations) with a range from 4.0 to 6.5; the average rating with turbulence was 5.9, with a range from 5.0 to 7.0 (seven evaluations). Some interpilot variability is evident in the ratings, with Pilot G's average ratings without turbulence and with turbulence being 5.8 and 7.0; the averages of these two ratings given by Pilots H, K, and M were 4.4 and 5.4. In particular, Pilot G's comments indicate difficulty in speed control and with bank-angle-wandering during turns, with turbulence again decreasing the speed control precision. The other three pilots, however, noted that the neutral static stability longitudinally was not an apparent problem under IFR in smooth air; the result is that their ratings for this configuration are about the same as for the baseline S01.

S03: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = -0.01 in./15°; δ_{RP}/β = -0.71 in./15° — This configuration has modified lateral velocity perturbations (primarily L'_v) to achieve a neutral lateral stick position gradient; the remaining gradients are equal to those of S01. The average pilot rating without turbulence was 4.6 (four evaluations) with a range from 4.0 to 5.0; the average pilot rating with turbulence was 6.0, with a range from 5.0 to 7.0 (four evaluations). In no turbulence, although the pilots noted some lateral trimming requirements, roll response was good and unaffected by the neutral lateral gradient. The major complaint on the configuration was poor airspeed control, even with the stable longitudinal stick gradient. Turbulence again had a large degrading influence on the flying qualities, primarily in increased pitch and speed control difficulties.

S04: δ_{ES}/V = -0.01 in./20 knots; δ_{AS}/β = -0.01 in./15°; δ_{RP}/β = -0.71 in./15° — In this configuration, both longitudinal and lateral velocity perturbation derivatives (primarily M_u and L'_v) were modified to achieve neutral longitudinal and lateral stick position gradients. The average rating without turbulence was 4.9, with a range from 4.0 to 6.5 (four evaluations); with turbulence, the average rating was 5.5, with a range from 4.5 to 7.0 (four evaluations). Again, as with S02, Pilot G was more sensitive to the neutral longitudinal gradient than Pilots H, K, and M (ratings of 6.5 and 7.0 versus average of 4.3 and 5.0). Pilot G complained of very difficult speed control plus some problems in maintaining bank attitude, both with and without turbulence, and considered the workload the maximum tolerable. In contrast, although comments by Pilots H and M indicate that speed control required attention, the desired performance was achievable. Turbulence apparently increased the workload level somewhat, but less than with configurations S01, S02, or S03, possibly due to the reduced excitation in pitch and roll together caused by $M_u \doteq L'_v \doteq 0$.

S05: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.19 in./15° — This configuration has reduced directional stiffness (N'_v), obtained through modifications to the lateral velocity perturbation derivatives, and therefore a less stable directional control gradient than the baseline configuration (S01). The average pilot rating without turbulence was 4.9, with a range from 4.0 to 6.5 (seven evaluations); with turbulence, the average rating was 5.7, with a range from 4.5 to 7.5 (seven evaluations). To some extent, Pilot G was again harder on the machine than Pilots H, K, and M (average ratings of 6.0 and 7.0 versus 4.4 and 5.0). Problems with directional looseness and heading control, plus roll attitude wandering, were generally noted, although turn coordination per se was not particularly called out, except by Pilot M. Some deterioration in speed control was noted by Pilot K once, although generally this characteristic was considered good. Turbulence did not degrade the ratings to the extent the combination of low directional stiffness and relatively high $|\phi/\beta|_d$ might have predicted. Some coupling of collective to yaw was noted.

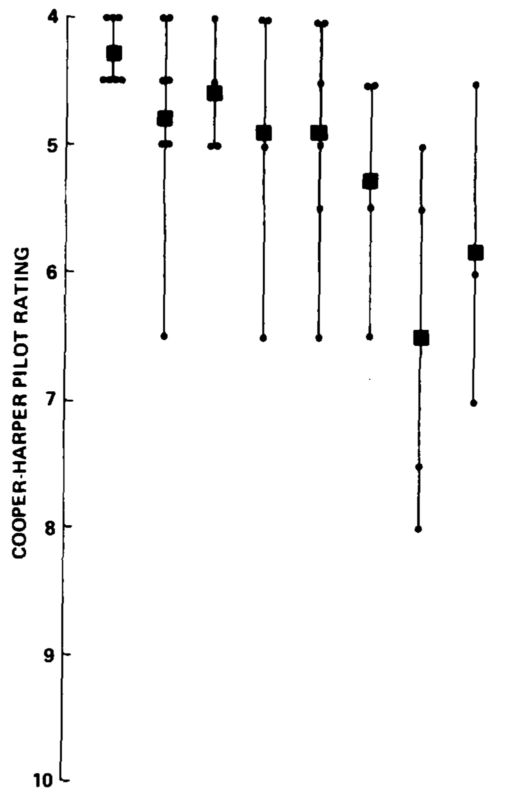
S06: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.03 in./15°; δ_{RP}/β = -0.18 in./15° — This configuration has a neutral lateral stick gradient in combination with a reduced directional control gradient, obtained through modifications to the lateral velocity perturbation derivatives (primarily L'_v, N'_v). The average rating without turbulence was 5.3, with a range from 4.5 to 6.5 (four evaluations); with turbulence, the average rating was 6.0, with a range from 5.0 to 7.0 (four evaluations). Good features of the configuration were considered to be speed and rate-of-climb control. The configuration characteristics that were poor were noted as looseness in sideslip leading to heading and roll control difficulties plus coupling due to power changes. Turbulence exacerbated sideslip and turn coordination problems, and degraded the speed control.

S07: $\delta_{ES}/V = -0.01$ in./20 knots; $\delta_{AS}/\beta = 0.57$ in./15°; $\delta_{RP}/\beta = -0.18$ in./15° — This configuration had a neutral longitudinal stick gradient (primarily through M_u) and a reduced directional control gradient (through modified N'_v). It received the worst ratings of the eight static gradient configurations: an average of 6.5 with a range from 5 to 8 (four evaluations) without turbulence, and an average of 7.3 with a range from 5.5 to 10.0 (four evaluations) with turbulence. Although responses to power changes for altitude control were considered decoupled and good, heading and speed control were poor, with large sideslip angles and difficult turn control. Pilot M, in particular, lost control of the configuration during the missed approach through lack of concentration on sideslip and a resulting rapid bleed-off of speed. Since the configuration was fairly poor in no turbulence, the influence of turbulence on the ratings was not too significant.

S08: $\delta_{ES}/V = -0.01$ in./20 knots; $\delta_{AS}/\beta = 0.03$ in./15°; $\delta_{RP}/\beta = -0.18$ in./15° — This configuration had neutral longitudinal and lateral stick position gradients (primarily M_u and L'_v, respectively) plus a reduced directional control position gradient. The average no-turbulence rating was 5.8, with a range from 4.5 to 7.0 (three evaluations); the average rating with turbulence was also 5.8, with a range from 5.0 to 7.5 (three evaluations). The airplane was described as difficult to trim in any axis, with constant corrections required for pitch and roll control as well as yaw and turn coordination. Turbulence had a negligible effect ($\leq \frac{1}{2}$ PR) on the pilot ratings.

Figures 6(a) and 6(b) illustrate all of the pilot rating data for these configurations without turbulence and with turbulence, respectively. As an aid in showing trends, both ranges and averages are included. It is emphasized, however, that the presentation of the averages should be considered as a qualitative indicator only: since the Cooper-Harper scale is ordinal rather than interval (ref. 23), it is not strictly correct to average ratings that are different by more than one.

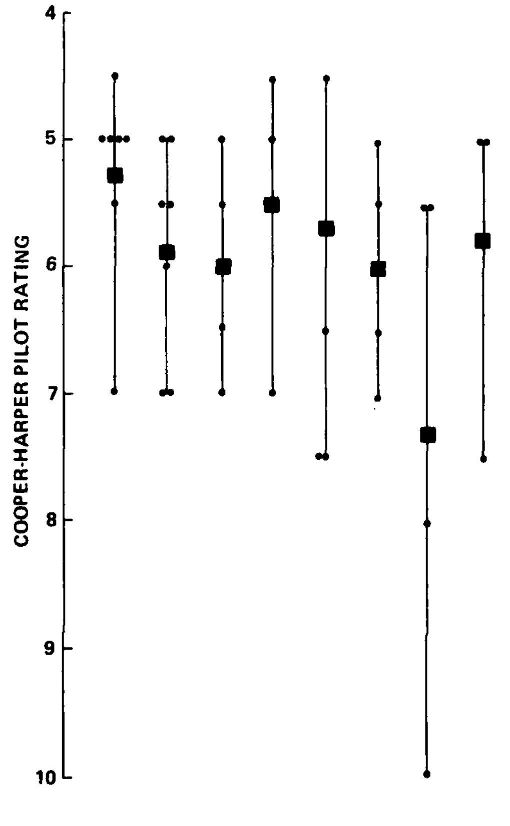
For the no-turbulence case, considering both the averages and the spread in ratings, it is apparent that the configuration with stable gradients in all axes (S01) is in fact rated the best. A neutral lateral stick gradient (reduced dihedral effect — S03) resulted in a minor degradation in pilot ratings, and little further degradation or difference was caused by neutral longitudinal gradient (S02), reduced directional gradient (S05), or neutral longitudinal and lateral gradients in combination (S04). Qualitatively, therefore, neutral longitudinal or lateral gradients, either solely or



-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01	δ_{ES}/V, in./20 knots
0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03	δ_{AS}/β, in./15 deg
-0.72	-0.72	-0.71	-0.71	-0.19	-0.18	-0.19	-0.18	δ_{RP}/β, in./15 deg
S01	S02	S03	S04	S05	S06	S07	S08	CONFIG. IDENTIFIER

(a) Without turbulence.

Figure 6.- Static gradient configurations — ratings of all pilots.



-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01	δ_{ES}/V, in./20 knots
0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03	δ_{AS}/β, in./15 deg
-0.72	-0.72	-0.71	-0.71	-0.19	-0.18	-0.19	-0.18	δ_{RP}/β, in./15 deg
S01	S02	S03	S04	S05	S06	S07	S08	CONFIG. IDENTIFIER

(b) With turbulence.

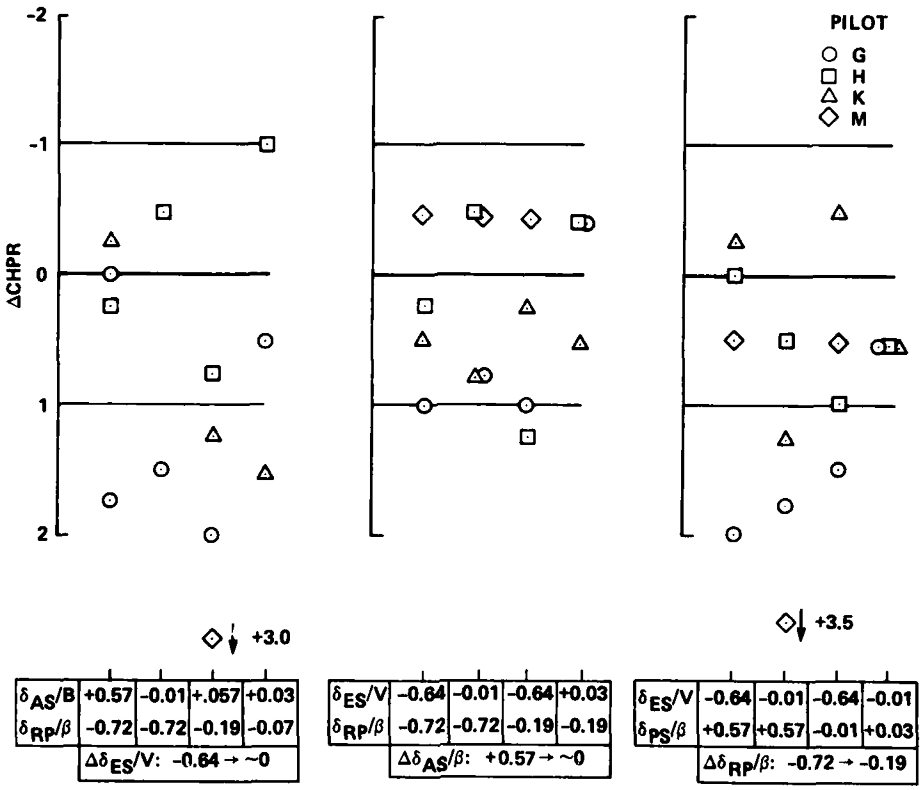
Figure 6.- Concluded.

together, were considered still adequate for the task and, for three of the four pilots, not significantly worse than the baseline configuration with all gradients stable. Although reduced directional static stability did not by itself appear to cause the problems that were expected, combining this reduction with longitudinal or lateral neutral gradients or both did result in markedly worse pilot ratings; the worst combination was configuration S07 with neutral longitudinal and reduced directional gradients. Qualitatively, therefore, the "combination-of-bads" effect was observed when one of the axes was directional, and in the case of configuration S07 resulted in an unacceptable (PR > 6) configuration.

In turbulence, the baseline configuration with all gradients stable (S01) is again rated the best. Although the in-turbulence rankings of configurations S02-S06 and S08 are different from the no-turbulence ones, there is very little difference among the ratings for configurations S02-S06 and S08 in turbulence, either in average or range. Configuration S07, with neutral longitudinal and reduced directional gradients is again clearly the worst of the eight. Qualitatively, only configuration S07 is clearly inadequate for the task in turbulence considering all the pilots, although Pilot G rated all the configurations except S01 as "inadequate performance with tolerable workload" (PR $\geq 6\frac{1}{2}$) in the presence of turbulence.

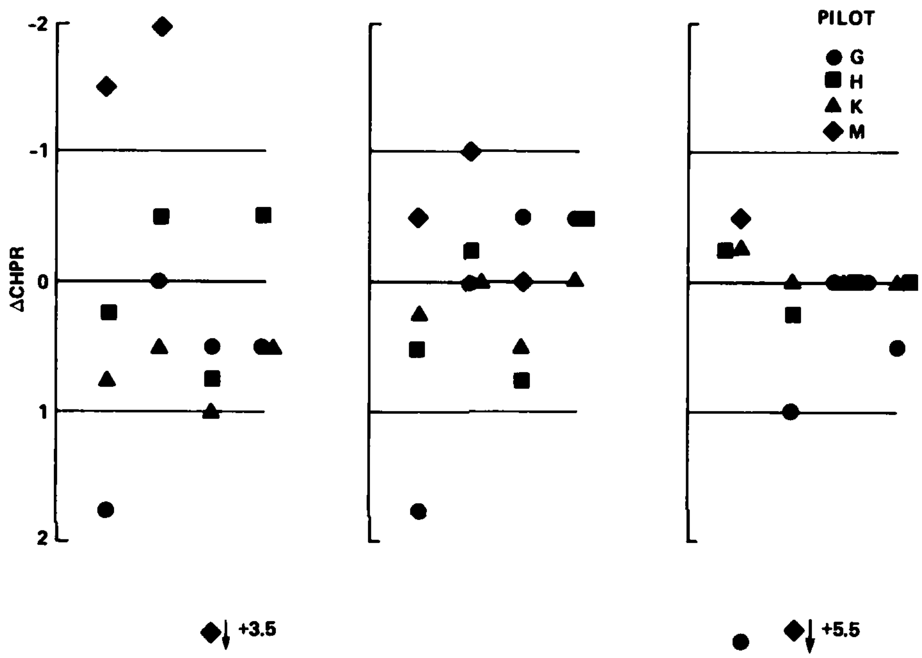
To ascertain any significant effects of the reduced static position gradients exhibited by configurations S02-S08, it is convenient to examine the change in pilot ratings between two configurations in which only one gradient has changed. In this experiment, it is possible to effect this comparison for configurations in which other parameters are held at "good" values (e.g., S02 with S01 to examine longitudinal stick gradient effects with lateral and directional gradients stable) and also for configurations in which other parameters may be at "degraded" values (e.g., S04 with S03 to examine longitudinal stick gradient effects with a neutral lateral gradient and stable directional gradient). Although the effects of the individual gradients would be expected to be most apparent with the first type of comparison, because the nominal pilot rating would be better, the latter type of comparison ("combination of bads") is useful as a means of exposing both unexpected harmony considerations and the sensitivity of the flying qualities to one parameter when others are off-optimum. It is emphasized that the baseline configuration for this aspect of this experiment (S01) was rated acceptable but unsatisfactory (PR = $4 \rightarrow 4\frac{1}{2}$ without turbulence), which implies that even with "good" gradients the aircraft had minor deficiencies and required moderate compensation to achieve the desired performance; hence the influences of the gradient changes may not be as clear as they would have been had the baseline been clearly satisfactory (e.g., PR = 2).

Figures 7(a) and 7(b) show the change in pilot rating among the configurations as a function of the gradients being changed. The shaded ±1 PR region represents an expected scatter in the pilot ratings — that is, only the data outside of this band can be expected to represent a significant change caused by the configuration differences. This judgment is based on the following facts. In this experiment, the configurations were presented to the pilots in a random order for evaluation rather than in a prescribed



(a) Without turbulence.

Figure 7.- Changes in pilots' ratings.



δ_{AS}/B	+0.57	-0.01	+.057	+0.03
δ_{RP}/β	-0.72	-0.72	-0.19	-0.07
	$\Delta\delta_{ES}/V$: -0.64 → ~0			

δ_{ES}/V	-0.64	-0.01	-0.64	+0.03
δ_{RP}/β	-0.72	-0.72	-0.19	-0.19
	$\Delta\delta_{AS}/\beta$: +0.57 → ~0			

δ_{ES}/V	-0.64	-0.01	-0.64	-0.01
δ_{PS}/β	+0.57	+0.57	-0.01	+0.03
	$\Delta\delta_{RP}/\beta$: -0.72 → -0.19			

(b) With turbulence.

Figure 7.- Concluded.

series of announced changes in their characteristics. It is generally recognized that intrapilot repeatability in experiments conducted in this manner is at least of the order of ±1 PR. Reference 24, for example, plotted a variety of data from two flight experiments for both intrapilot and interpilot variability checks; in general, a spread of ±2 PR was required to account for a large percentage (e.g., >90%) of the data. In this experiment, if intrapilot repeats of all configurations are considered (a total of 17 ratings), all but one, or 94%, are within ±1 PR both with and without turbulence. For this reason, this threshold appears valid for use in determining significant influences of the gradients.

Consider initially the data obtained without turbulence (fig. 7(a)). The influence of reducing the longitudinal gradient to zero was apparent for most of the pilots only when the directional gradient was the lower value (configuration S05 going to S07), in which case the change to a neutral gradient longitudinally was significantly down-rated. Pilot G in general gave significantly worse ratings to configurations with neutral longitudinal static gradients than to equivalent configurations with stable gradients; this was not true of the other three pilots. On average, therefore, it must be concluded that without turbulence no significant influence of longitudinal gradient between stable and neutral is evident unless the directional statics are poor.

The influence of reducing the lateral control position gradient to zero had a negligible effect without turbulence regardless of the other gradient characteristics. The sole point outside the ±1 PR band was for Pilot H going from configuration S05 to S06, and his low rating of S06 appears to have been influenced by noting the mild divergent long-term oscillation in hands-off VFR flight. Although it had been expected that the almost neutral effective dihedral effect used to obtain a neutral lateral gradient might be objectionable (no capability to roll with the pedals, for example), the rating data do not show such an effect. Without turbulence, therefore, no degrading effect on flying qualities of a neutral lateral gradient is evident.

With regard to reducing the directional gradient, the results are similar to those for reducing the longitudinal gradient. Again, the worst combination is when a configuration with neutral longitudinal gradient (S02) also has a reduced directional gradient (S07), with most of the pilots giving significantly worse ratings for the latter case. Again, only Pilot G consistently gave significantly worse ratings to configurations with a reduced directional gradient than to equivalent configurations with the higher gradient. On average, therefore, little significant difference between the two directional gradients examined in this experiment was exhibited unless the longitudinal gradient was neutrally stable.

Figure 7(b) shows the same information for ratings given in the presence of turbulence. No uniform trend for the influence of the longitudinal gradient is observable, although several rating changes were greater than ±1. Pilot M, in particular, rated a neutral longitudinal gradient better than a stable one in turbulence as long as the higher directional gradient existed in a configuration. The likely reason is that turbulence sensitivity in pitch is reduced with the small M_u for the neutral longitudinal gradient case; however, only Pilot M appears to have been sensitive to it. Pilot G, on the contrary, again rated a neutral longitudinal gradient with other gradients stable significantly lower than the stable gradient configuration. The generally significant changes with longitudinal gradient when the directional gradient is reduced were not as evident with turbulence as they were without it. As with the no-turbulence ratings, therefore, on the average no significant degrading effect of neutral longitudinal gradient on flying qualities is evident with turbulence.

The influence of neutral lateral or reduced directional gradients with turbulence can be seen to be similar to the results without turbulence. Comparing ratings given to configurations with a stable lateral gradient with those for equivalent configurations with a neutral lateral gradient, no significant difference is apparent, on the average. Similarly, no significant difference as a result of a decreased directional gradient exists on the average for all the pilots, even for the change from configuration S02 to S07; note, however, that for Pilot M the change in going from S02 to S07 with turbulence was $\Delta PR = 5.5$, because he lost control of S07. It is important to note here that the effect of turbulence was generally to reduce differences among the static gradient configuration. For example, Pilot G rated all of configurations S02-S08 between 7 and 8 with turbulence. Therefore, the influence of configuration changes when evaluations with turbulence are considered should not be expected to be as noticeable as without turbulence. This effect of turbulence will be discussed in more detail later.

In summary, the influences on pilot rating of combined force and position static gradients as examined in this experiment are:

1. Stable force and position gradients in all three rotational axes received the best pilot ratings with smallest data scatter of the configurations examined. This configuration (S01) met all the static and dynamic requirements expressed in the Airworthiness Criteria (ref. 2), and was rated adequate but unsatisfactory by all pilots for the task considered.

2. No significant influence on pilot ratings — on the average — was shown by changing the longitudinal gradient alone from stable to neutral, changing the lateral gradient alone from stable to neutral, or reducing the directional gradient alone by a factor of 4. These configurations (S02, S03, S05) were rated adequate but unsatisfactory by all pilots without turbulence, although a fairly large scatter in the ratings was evident. On this basis, for the task and evaluation procedure used in this experiment, neutral longitudinal or lateral gradients would be permitted, given good characteristics in the other axes.

3. No significant difference in pilot ratings was evident between the baseline configuration (S01) with all gradients stable and configuration S04 with both longitudinal and lateral gradients being neutral, either with or without turbulence. On this basis, neutral longitudinal and lateral gradients together could be permitted, given good directional characteristics.

4. The combination of neutral longitudinal and reduced directional gradients was rated the worst of the configurations examined; pilot ratings indicated marginally adequate to inadequate suitability for the task. On this basis, permitting neutral longitudinal gradients must be qualified by requiring fairly high directional stiffness (hence the higher gradient).

5. Although on average the pilot ratings for all the static configurations except S07 indicate adequate suitability without turbulence, Pilot G rated all these configurations, except S01 and S03, as borderline adequate (PR = 6½) or worse. Hence, the sensitivity of those types of configurations to pilot techniques is evident, and the average influences of the gradients described above must be qualified to some extent on this basis.

It is important to emphasize two qualifying factors with reference to the influences of the static force and position gradients discussed above. First, although the experiment was one of single-pilot IMC operations, ancillary tasks such as chart reading, navigation, or communications were not included. Therefore, the results should be considered in the light of full-attention pilot action; they may in fact be more appropriate to a two-pilot situation. Second, although the results have been discussed with reference to static force and position control gradients, these characteristics imply different long-term dynamics or modal characteristics of the configurations, as was described in the section on experimental design.

Static Position-Only Configurations

In this experiment, the influence of control-position gradient independent of force gradient was examined by repeating configurations S01-S06 with the force feel system turned off; these additional configurations are S13-S18. It is important to note that configurations S13-S18 had, therefore, "limp stick" characteristics: the force gradient was zero but the breakout forces (friction) were also zero. All other characteristics of configurations S13-S18 corresponded exactly to those of configurations S01-S06, respectively. The pilot rating data are summarized below.

S13: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.72 in./15° — Without turbulence, this configuration received an average pilot rating of 5.8, with a range from 4.5 to 8.0 (seven evaluations); with turbulence, the average rating was 6.4, with a range from 5.0 to 8.5 (seven evaluations). The major objectionable deficiency was the lack of force gradients, with pilot comments indicating more apparent coupling with power changes (even though M_{δ_C}, and in fact all airplane parameters, was the same as for S01, for which no power-coupling problems were noted) plus the need for a high scan rate to avoid inadvertent or overly large inputs. Turbulence considerably degraded the performance the pilot saw.

S14: δ_{ES}/V = -0.01 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.72 in./15° — The no-turbulence ratings average 6.5, with a range from 6.0 to 7.0 (two evaluations); with turbulence, the ratings averaged 6.8 with a range from 6.0 to 7.5 (two evaluations). In addition to the problems with the lack of force gradient mentioned for S13, one of the Pilots (H) found that speed control was degraded because of the neutral control position gradient. Note that with the same neutral gradient in position, but with the force-feel ON, Pilot H noted a problem in trimming for speed control; nevertheless, he found that speed control in general was not as bad as expected, even though the longitudinal force-with-velocity gradient was zero.

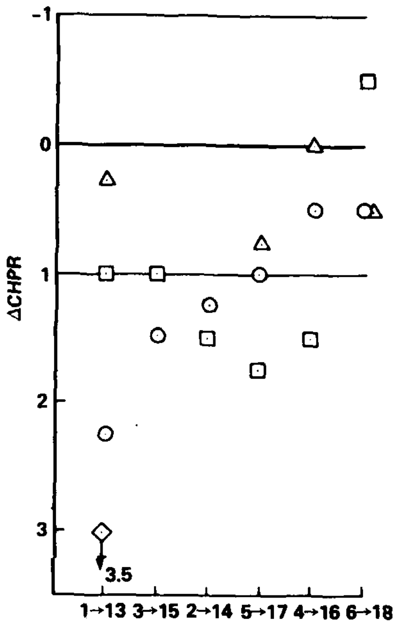
S15: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = -0.01 in./15°; δ_{RP}/β = -0.71 in./15° — The average rating for no turbulence was 6.0, with a range from 5.5 to 6.5 (two evaluations); with turbulence, the ratings averaged 6.5, with a range from 6.0 to 7.0 (two evaluations). From the two evaluations, it appears that, although the lack of force-feel or trim centering was still objectionable, because of the concentration required for attitude control, there is an indication that the performance was not as bad as expected (even though the aircraft was still rated barely adequate).

S16: δ_{ES}/V = -0.01 in./20 knots; δ_{AS}/β = -0.01 in./15°; δ_{RP}/β = -0.71 in./15° — The average rating without turbulence was 5.8, with a range from 5.0 to 7.0 (three evaluations); with turbulence, the average was 6.2, with a range from 5.0 to 8.0 (three evaluations). Pilot comments were similar to those for the other no-force configurations: too much workload for attitude control, performance better than expected.

S17: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.57 in./15°; δ_{RP}/β = -0.19 in./15° — The average rating without turbulence was 6.0, with a range from 5.0 to 7.0 (three evaluations); the average rating with turbulence was 6.7, with a range from 5.5 to 8.0 (three evaluations). Pilot G commented that speed control was poor, with lateral-directional motions feeding in, but Pilot K felt he had good speed and turn coordination control, with the only workload being not to move the stick unless desired. Pilot H also noted high workload and poor speed control performance; it is interesting to note that his rating was much worse for this configuration than it was for S05, which had the same characteristics but with the force-feel ON.

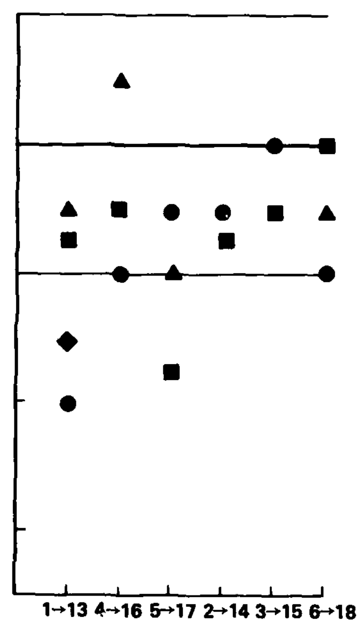
S18: δ_{ES}/V = -0.64 in./20 knots; δ_{AS}/β = 0.03 in./15°; δ_{RP}/β = -0.18 in./15° — The average rating without turbulence was 5.7, with a range from 5.0 to 7.0 (three evaluations); with turbulence the average was 6.3, with a range from 5.5 to 8.0. Pilots H and K had few complaints — in fact, pilot K liked the lack of forces. Pilot G, however, noted that considerable work was involved in trying to hold the right attitude and contend with sideslip, with turbulence exacerbating the difficulties.

The change in pilot rating, for a given set of dynamics and position gradients, caused by having the forces set to zero is shown in figures 8(a) and 8(b) without and with turbulence, respectively. As can be seen from the figures, for the no-turbulence case, a significant rating degradation ($\Delta PR > 1$) occurred for at least one pilot for all the configurations except S06 when they are flown with the control-force/displacement relationship at zero. As noted in the comments, the inability to achieve a trim and the increased attention required to aircraft attitude and control input magnitude



-0.64	-0.64	-0.01	-0.64	-0.01	-0.64
+0.57	-0.01	+0.57	+0.57	-0.01	0.03
-0.72	-0.72	-0.72	-0.19	-0.72	-0.18

(a)



-0.64	-0.01	-0.64	-0.01	-0.64	-0.64
0.57	-0.01	0.57	0.57	-0.01	0.03
-0.72	-0.72	-0.19	-0.72	-0.72	-0.19

(b)

(a) Without turbulence.

(b) With turbulence.

Figure 8.- Change in pilot ratings due to force-feel OFF.

were very objectionable characteristics with the forces off, regardless of control-position gradients. With turbulence, a corresponding degradation was not exhibited. Two reasons account for this: (1) the lack of a trim point was less of a problem because of the continual disturbance of the aircraft by the turbulence, and (2) the ratings with turbulence with the force-feel ON were generally close to minimum adequate (PR ≈ 6, cf. fig. 1(b)) to start with.

The influences of control position gradients with no forces, as well as the effects of a control-force/displacement relationship of zero can be summarized as follows.

1. No significant influence of neutral versus stable longitudinal or lateral control position gradient or of a reduced directional control position gradient, was shown by the configurations without a control-force/displacement gradient as investigated in this experiment. Without turbulence, the configurations were rated as marginally adequate (PR ≈ 6); with turbulence they were rated on average as borderline inadequate (PR $\geq 6\frac{1}{2}$).

2. The lack of a control-force/displacement relationship resulted in a significant degradation in pilot ratings for the no-turbulence condition when compared with ratings for equivalent configurations with a 0.5 lb/in. (pitch/roll) relationship. A nonzero control-force/displacement relationship permits the pilot to establish trim control positions and avoid inadvertently large inputs, both of which were indicated by pilot comments to be desirable characteristics in IMC flight.

3. Because the zero force-displacement characteristic was examined with no breakout force (such as friction), it is possible that some improvement in the flying-qualities results for these configurations could be obtained by adding friction (e.g., the controls would hold a position by themselves). It is doubtful, however, that problems with overly large inputs and increased attention to aircraft attitude would be alleviated.

Control Augmentation Configurations

As was discussed in the section on the design of the experiment, four types of SCAS's were designed for configurations having the lower level of static control position gradients in all three axes. To provide comparability with the previous experiment (ref. 6), these control systems were investigated for teetering- and articulated-rotor helicopter configurations in addition to the hingeless configuration used for the static gradient examinations discussed previously. The configuration identifiers for this portion of the examination are summarized in table 8.

TABLE 8.- CONTROL AUGMENTATION CONFIGURATION IDENTIFIERS

Control system/rotor configuration	Hingeless	Teetering	Articulated
Rate damping, input decoupling	S08	S10	S12
Above plus directional stiffness	S21	S26	S29
Directional stiffness plus attitude command	S24	S27	S30
Directional stiffness plus rate-command-attitude-hold	S25	S28	S31

One additional configuration for both the teetering and articulated configurations (S09 and S11, respectively) was also investigated, using the rate damping control system — the corresponding hingeless configuration was S05. It had stable pitch and roll static gradients, but a reduced directional gradient.

A brief summary of the evaluations of each configuration is given in the following paragraphs. The summaries are grouped according to the rotor type of the baseline configuration; complete comments are given in appendix C. The inferences that can be drawn concerning the efficacy of each type of augmentation are then discussed. It is emphasized that these inferences, for these configurations, are predicated on the levels of augmentation used, the assumption of full-authority implementations, and the baseline characteristics of the hingeless-, teetering-, and articulated-rotor helicopter configurations with low longitudinal and lateral static gradients that served as the basis for the control system implementations.

Hingeless-rotor configurations (S08, S21, S24, S25) —

1. Rate damping (S08): The pilot ratings and comments for this configuration were described in a previous subsection. Configuration S08 formed the basis for the higher level augmentation concepts and had neutral longitudinal and lateral gradients plus reduced directional stiffness; recall that the average rating both with and without turbulence was 5.8, with pilot comments indicating trimmability and turn coordination problems.

2. Rate damping plus directional stiffness (S21): This control system configuration added δ_{RP}/β feedback to S08 to acheive a higher Dutch roll frequency and improved turn-following capability ($\omega_n \cong 2.5$); some additional yaw rate feedback was also used to maintain the damping ratio at $\zeta \geq 0.7$. The average rating without turbulence was 4.4, with a range from 3.5 to 5.0 (four evaluations); with turbulence, the average rating was 5.1, with a range from 3.5 to 7.0 (four evaluations). Pilots G, H, and M felt that the directional stability and turn coordination of this configuration were good features, although Pilot K complained of turn coordination and overbanking problems. Airspeed control was considered poor; it was, in fact, the most objectionable deficiency for the no-turbulence condition for Pilots G and M.

Turbulence degraded the turning performance and also made speed control a higher workload situation, so that for Pilot G the configuration was unacceptable with turbulence.

3. Attitude command plus directional stiffness (S24): This control system added feedback of Euler pitch and roll attitude to the longitudinal and lateral sticks, respectively. The same level of pitch and roll-rate feedback used in the rate-damping control system were maintained, as was the augmented directional stiffness. The average rating without turbulence was 2.8, with a range from 2.0 to 3.0 (seven evaluations); with turbulence, the average rating was 3.1 with a range from 2.0 to 4.0 (seven evaluations). The no-turbulence ratings agreed exactly with the ratings assigned to effectively the same configuration in the reference 6 experiment; that is, 2 and 3. Pilot comments indicate that almost all characteristics of the configuration were desirable. Mildly unpleasant deficiencies were the need to do some pitch attitude changing with power to maintain speed and the need to hold a lateral force during turns. Turbulence had very little degrading influence on either performance or workload.

4. Rate-command-attitude hold plus directional stiffness (S25): This control system added proportional-plus-integral prefilters to the pitch and roll channels of the attitude command system described above; everything else was the same. The average no-turbulence rating was 2.8 with a range from 2.5 to 3.0 (six evaluations); with turbulence, the average rating was 3.4, with a range from 3.0 to 4.5 (six evaluations). As with the attitude command control system for this helicopter configuration, almost all characteristics of the configuration were considered desirable; note that, for example, Pilot G indicated that he did not mind the lack of any apparent static stability. Turbulence had some degrading effects on airspeed and turn performance, although not large.

Teetering-rotor configurations (S10, S26-S28) –

1. Rate damping (S10): The baseline teetering-rotor helicopter configuration with a rate-damping control system was designed to have minimum static gradient characteristics, similar to those for configuration S08 (the hingeless configuration); for configuration S10, these characteristics were $\delta_{ES}/V = -0.02$ in./20 knots, $\delta_{AS}/\beta = 0.02$ in./20 knots, and $\delta_{RP}/\beta = -0.34$ in./15°. The average no-turbulence rating was 6.2, with a range from 5.0 to 8.0 (five evaluations); with turbulence, the average rating was 6.7, with a range from 5.0 to 8.5 (five evaluations). The configuration was considered particularly objectionable in yaw, with weak stiffness for airspeeds below 60 knots leading to heading control problems and coupling into airspeed. Turbulence degraded airspeed control and generally made the configuration "worse all around."

2. Rate damping plus directional stiffness (S26): The directional stiffness (N'_v) and yaw rate damping were augmented to obtain a Dutch roll mode similar to that of the hingeless-rotor configuration S21 ($\omega_n \simeq 2.5$). The average no-turbulence rating was 4.5, with a range from 4.0 to 5.0 (three evaluations); with turbulence, the average rating was 5.8, with a range from

5.0 to 7.0 (three evaluations). Without turbulence, the pilots noted the absence of problems with sideslip excursions, and considered pitch and roll response predictability and decoupling good features. The most objectionable feature had to do with speed control, with a flat attitude-to-airspeed relationship causing problems, particularly in the missed approach. Turbulence degraded the acceptability of the configuration considerably. The turbulence excited the directional axis considerably because of the augmented N'_v, leading to both heading control difficulties and some degradation in speed control.

3. Attitude command plus direction stiffness (S27): This configuration added pitch and roll attitude feedback to achieve attitude command dynamics similar to those of the hingeless configuration (S24). The average no-turbulence rating was 2.6, with a range from 2.0 to 3.0 (four evaluations); the average rating with turbulence was 3.1, with a range from 2.0 to 4.0 (four evaluations). Without turbulence, the configuration provided good performance with very low workload; the only features considered undesirable were the requirement to change attitude with power to maintain speed and questions about the control sensitivities (Pilot H thought the control throws were too long, and Pilot M preferred the longer throws). With turbulence, coupling into the speed control caused some degradation. Note that in this experiment the teetering-rotor and hingeless-rotor configurations with an attitude command control system received identical ratings in the satisfactory range. In the previous experiment (ref. 6), the teetering-rotor configuration with this control system was rated acceptable, but not satisfactory (PR = 4) without turbulence; the difference is probably due to the somewhat higher level of attitude augmentation used in this experiment, the fact that the longitudinal stick gradient was unstable in the previous experiment even with attitude command augmentation, and perhaps the somewhat higher directional stiffness used in this experiment.

4. Rate-command-attitude-hold plus directional stiffness (S28): This configuration added proportional-plus-integral prefilters in pitch and roll to the attitude command system discussed above. The average no-turbulence rating was 3.3, with a range from 3.0 to 4.0 (three evaluations); with turbulence, the average rating was 3.8 with a range from 3.5 to 4.0 (three evaluations). Although considered satisfactory without turbulence, two of the pilots noted some problems with speed control, caused by the need to change attitude with power to maintain speed. With turbulence, the directional axis was apparently stirred up causing a higher workload and wandering in heading — Pilot H in particular advocated a heading-hold control system.

Articulated-rotor configurations (S12, S29, S30, S31) -

1. Rate damping (S12): This configuration was designed to have static control position gradients of δ_{ES}/V = 0.01 in./20 knots, δ_{AS}/β = 0.18 in./15°, and δ_{RP}/β = -0.20 in./15° around zero sideslip. As was discussed in the design section of this report, however, the selection of the fuselage-empennage-fin geometric characteristics for the articulated-rotor helicopter configuration led to an unforeseen difficulty in the directional stiffness characteristics. Specifically, the very nonlinear $N'_v(v)$ caused by tail-fin stall led to a statically unstable directional stiffness at positive sideslips

when the directional gradient at zero sideslip was reduced from the nominal value. As a result, configuration S12 (with neutral longitudinal and reduced lateral gradients also) was found to be essentially unflyable and was not evaluated. It is emphasized, however, that the difficulties with this configuration were caused by the selection of the tail geometric characteristics and not by the articulated rotor selected.

2. Rate damping plus directional stiffness (S29): This configuration used the rate-damping control system with the inherent directional stiffness of the articulated-rotor helicopter configuration (δ_{RP}/β = -0.86 in./15° at zero sideslip). Although for the hingeless- and teetering-rotor configurations additional directional augmentation was used to increase the Dutch roll frequency, the baseline articulated-rotor configuration had a frequency of about ω_n = 2.2 rad/sec at zero sideslip; as a result, further augmentation was not considered necessary. Again, however, the influence of fin stall reduced the effective stiffness significantly for positive sideslips, which was not accounted for in the design. The ratings for the configurations with "plus directional stiffness" (S29, S30, S31) therefore must be qualified accordingly. For S29, the average no-turbulence rating was 4.8, with a range from 4.5 to 5.0 (two evaluations); with turbulence, the average rating was 5.2, with a range from 5.0 to 5.5 (two evaluations). Pilot H considered the high sideslip required to trim the ball unrealistic, whereas Pilot K seemed to find turn coordination a good feature. Turbulence did not alter the rating significantly, although Pilot K indicated some additional speed control problems.

3. Attitude command plus directional stiffness (S30): As in the hingeless-rotor (S24) and teetering-rotor (S27) configurations, this configuration added feedback of pitch and roll attitudes to achieve an attitude command control system. The average no-turbulence rating was 4.2, with a range from 3.0 to 6.0 (three evaluations); with turbulence, the average rating was 4.5, with a range from 3.5 to 6.0 (three evaluations). Pilot H differed significantly from Pilots G and K in his evaluations of this configuration (ratings of 6 and 6 versus averages of 3.2 and 3.8). Apparently, the sideslip problem was a contributor in addition to the control sensitivities used in the design, for Pilot H complained of large control throws and poor speed control and flew the entire approach with a large positive sideslip. On the other hand, Pilots G and K considered the no-turbulence performance good, with only minor complaints about directional weakness and speed control sloppiness; turbulence added to the workload a little for them, and they pointed out the need for directional improvement.

4. Rate-command-attitude-hold plus directional stiffness (S31): This configuration added proportional-plus-integral prefilters to the attitude command control system. The average no-turbulence rating was 4.2, with a range from 4.0 to 4.5 (two evaluations); the average rating with turbulence was 4.8, with a range from 4.5 to 5.0 (two evaluations). The airplane was rated as unsatisfactory because of speed control problems caused primarily by the need for different nose attitudes in left and right turns; Pilot K felt in addition that the response of speed to pitch attitude changes was slow.

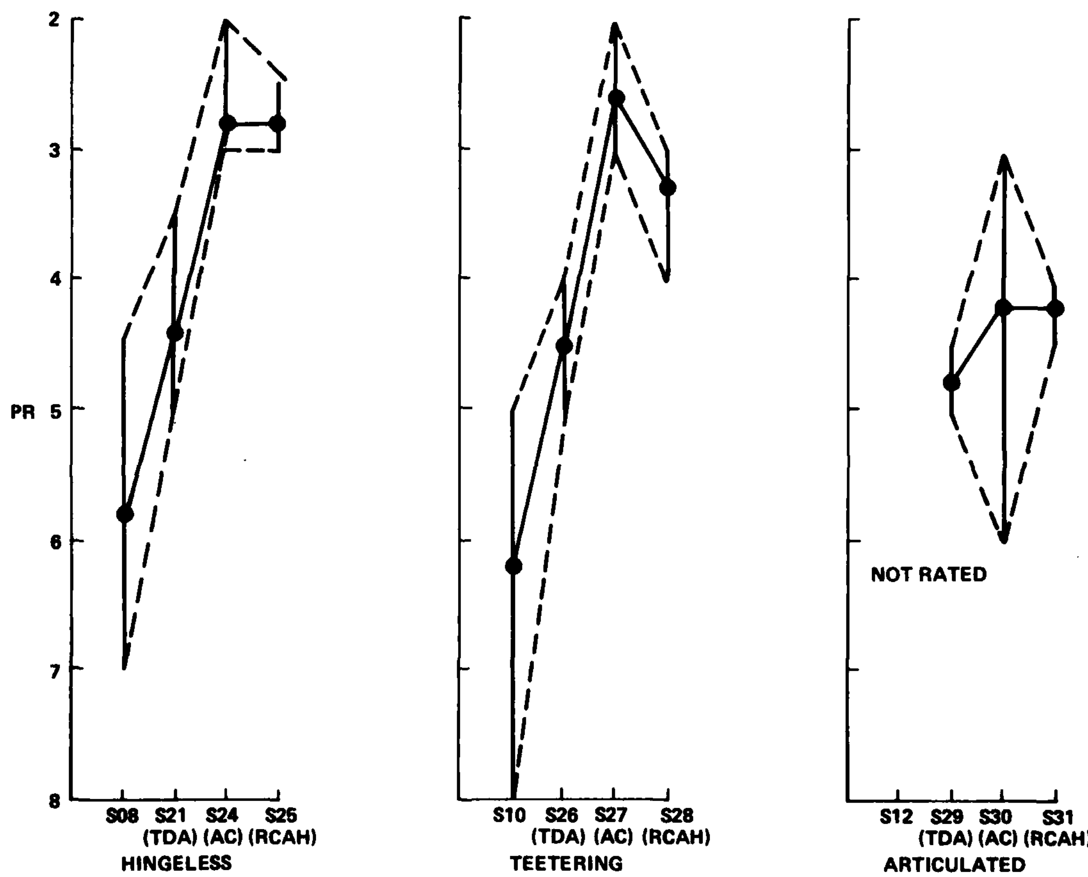
Turbulence was considered to aggravate the coupling problems, although the change in pilot rating is not significant.

Figures 9(a) and 9(b) summarize the pilot ratings for the four levels of augmentation considered in this experiment and the three baseline configurations employing hingeless, teetering, and articulated rotors. Again, the average pilot ratings are shown primarily to emphasize the trends. As can be seen, augmenting the directional stiffness alone resulted in a significant improvement in pilot rating, on the average, for both the hingeless- and teetering-rotor configurations. For the hingeless-rotor configuration, reference to configuration S04 may also be made, which had the higher directional gradient but neutral longitudinal and lateral gradients; referring to figure 1, it may seem that the average ratings for configuration S21 (with turn-following directional augmentation — TDA) are comparable to those for S04; they are actually somewhat ($\sim$ 0.5 PR) better because of the even higher Dutch roll frequency and turn-following capability provided by the augmentation. This type of augmentation alone, however, does not provide characteristics that can be rated satisfactory (PR < 3.5), primarily because no assistance for airspeed and attitude control is added.

Pitch and roll attitude command provided a significant improvement for all the pilots when added to the directional augmentation for the hingeless and teetering configurations (S24, S27). In fact, the significant improvement of the pilot ratings over the TDA configurations (S21, S26) suggests that control of attitude and speed were the major difficulties with the TDA configurations, a suggestion that is supported by the pilot comments.

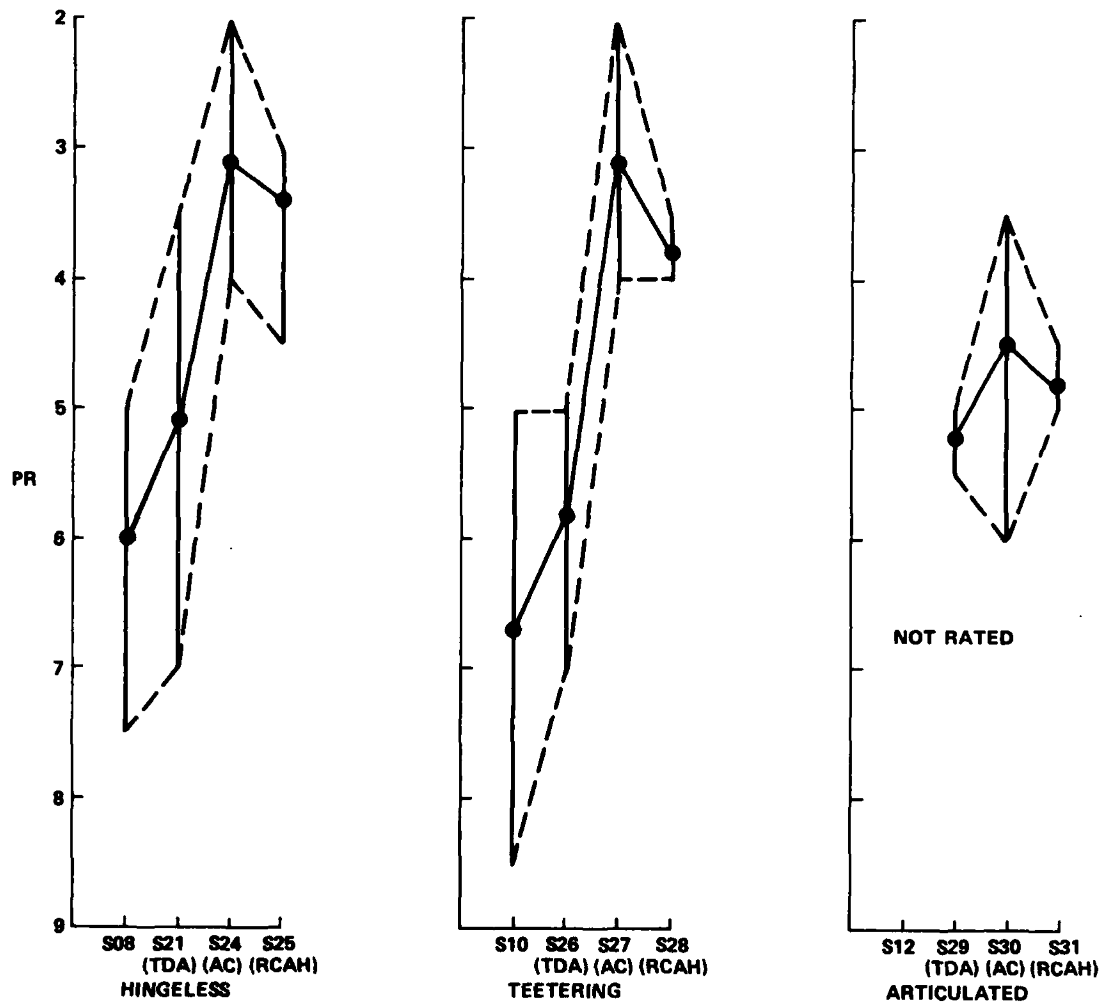
Referring to the actual ratings as shown in figure 9, it can be seen that the attitude command control systems investigated in this experiment provided, on the average, a satisfactory capability with and without turbulence for hingeless- and teetering-rotor configurations; these were the only control system configurations investigated that were rated PR < 3.5 by each pilot at least once. Considering the articulated-rotor configuration with attitude command augmentation (S30), however, one of the three pilots (H) rated it marginally adequate (PR = 6) with and without turbulence, with no improvement over the directional augmentation alone. As has been discussed, Pilot H flew both approaches with this configuration at a large positive sideslip, thereby stalling the fin and reducing the directional stability significantly. The other two pilots rated the configuration borderline satisfactory (PR $\sim$ 3.5) in and out of turbulence.

Adding proportional-plus-integral prefilters in the pitch and roll channels to effect a rate-command-attitude-hold (RCAH) implementation made no significant difference on average compared to the attitude command implementation for any of the three rotor configurations (S25, S28, S31), although a trend to slightly worse average ratings with the RCAH implementation is evident in figure 9, particularly with turbulence. Although pilot comments indicated some preference for having an attitude rate response to a control input, they also indicated some additional problems with speed control in turbulence, perhaps caused by the low breakout and gradient forces in conjunction with the integrator; for all three rotor configurations; therefore,



(a) Without turbulence.

Figure 9.- Influence of augmentation on ratings.



(b) With turbulence.

Figure 9.- Concluded.

no significant difference in pilot rating between attitude command and RCAH implementations was found without turbulence, but a small degradation with RCAH was evident with turbulence.

The influences on pilot rating of the four levels of stability and control augmentation investigated in this experiment can be summarized as follows:

1. Rate-damping-only augmentation in pitch, roll, and yaw ranges from inadequate ($PR \geq 7$) to adequate-but-unsatisfactory ($PR = 4$) depending on static gradient characteristics as well as other configuration details (e.g., rotor type). Neither in this experiment nor in the previous experiment (ref. 6) was it possible to devise a rate-damping control system yielding satisfactory ($PR \leq 3.5$) characteristics for the instrument nonprecision approach task, assuming representative baseline helicopter configuration details.

2. Increasing directional stiffness and damping with rate damping in pitch and roll were shown to provide a significant improvement for both the hingeless- and teetering-rotor configurations when the baseline characteristics included neutral longitudinal and lateral gradients and fairly weak ($\omega_{DR} \sim 1.0$ rad/sec) directional gradient characteristics. The improvement resulted in an adequate but unsatisfactory aircraft for both of these rotor types. Similar ratings were obtained for the articulated-rotor configuration, although no direct comparison with an equivalent weak directional baseline was made. For the hingeless-rotor configurations this result is comparable to that shown in the static gradient configurations described earlier; with a good directional gradient, the configuration with neutral longitudinal and lateral gradients (S04) was also adequate but unsatisfactory.

3. Attitude augmentation in the pitch/roll channels, implemented as either attitude command or rate-command-attitude-hold, was required to obtain a satisfactory capability. Both the hingeless- and teetering-rotor attitude command configurations were rated satisfactory, with the levels of pitch/roll attitude augmentation used in this experiment, in conjunction with increased directional aerodynamic stiffness.

4. No significant difference between attitude command or rate-command-attitude-hold implementations was observed, although the attitude command implementation ratings were marginally the better of the two, particularly with turbulence.

5. Although not examined in this experiment, some pilot comments indicate that heading-hold augmentation in addition to attitude command would be highly desirable.

It is emphasized again that the results of the augmentation types for the articulated-rotor configurations were compromised by a nonlinear directional stiffness, which decreased significantly with positive sideslip, even when augmented. It is possible that results similar to those for the hingeless- and teetering-rotor configurations would have been obtained for the articulated-rotor cases had the empennage characteristics been selected differently.

Further, it is important to note that the "lowest" level of SCAS in this experiment included control input decoupling. This type of augmentation is not commonly used in practice, and yet collective-to-yaw decoupling, for example, has been shown to provide significant improvements in previous experiments (refs. 6, 14). Finally, recall that the augmentation for the teetering-rotor system was designed to achieve dynamics similar to those of the hingeless rotor, irrespective of the realizability of the resulting required gains. In the reference 6 experiment, lower gains were used for the teetering rotor because of this consideration, and the flying qualities of the resulting configurations were not so good as in this experiment.

Influence of Turbulence (All Configurations)

Each configuration in this experiment was given a rating in smooth air (no turbulence) and in "representative" low-level turbulence, the model for which was described earlier. To obtain an indication of the influence of turbulence across all the configurations, the changes in pilot rating going from no turbulence to turbulence are shown in figure 10 for all the pilots. Again, ±1 PR is taken as a measure of significant influences. As can be seen, significant degradations in pilot rating, for one or more pilots, occurred when turbulence was introduced on the following configurations: S01 through S07, S21, S25, and S26.

Consider initially the six static gradient rate-damping-only configurations. Recall that in this experiment the gradients were modified by altering primarily three derivatives: M_u, L'_v, N'_v; these derivatives are also the major turbulence input effectiveness derivatives for the configurations investigated here, so that a neutral or reduced gradient in one axis also implies reduced moment excitations from turbulence in that axis. On this basis, it is interesting to note that configuration S04, with M_u, $L_v' \to 0$, did not show a significant degradation in turbulence, although all the hingeless-rotor configurations with one of these derivatives at a "good" stable value did. In terms of single-pilot IFR, it is important to note that the influence of turbulence for the rest of the hingeless static gradient configurations was significant for at least one pilot, even with the low-level turbulence considered. As was discussed earlier, however, most of these configurations were rated on average as adequate (PR < 6.5) with turbulence as well without it.

The teetering-rotor (S09, S10) and articulated-rotor (S11) rate-damping configurations did not exhibit a similar sensitivity of rating to turbulence. For the articulated-rotor configuration, the no-turbulence ratings were very poor (PR = 8, 8.5), so that the influences of turbulence were probably masked by the poor flying qualities of the basic aircraft. Configuration S09 was designed to have gradient characteristics similar to the hingeless-rotor S05: stable longitudinal/lateral in combination with reduced directional. Although the stick gradients turned out to be almost the same for the two configurations (appendix A), for the teetering-rotor configuration the values of M_u and L_v' to achieve them are about one half the values for the hingeless-rotor configuration, and hence the excitations from turbulence in pitch and roll are

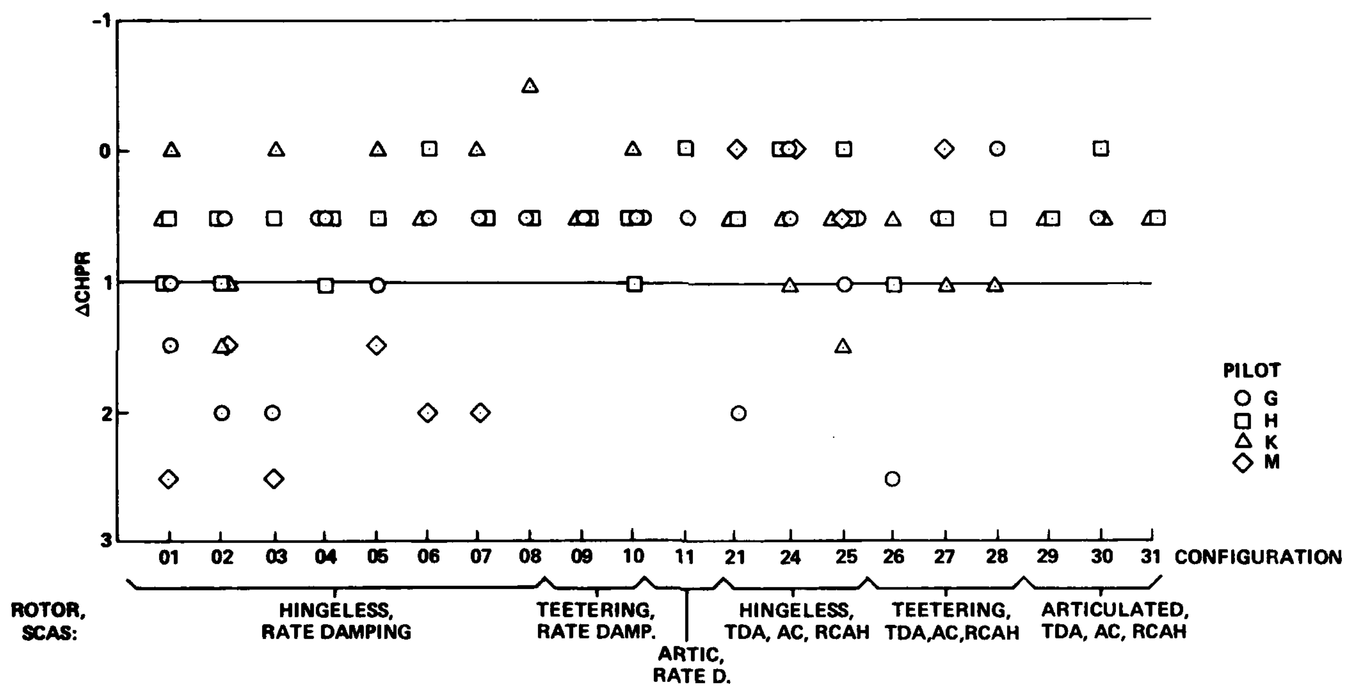


Figure 10.- Change in pilots' ratings with turbulence (force-feel ON configurations).

attenuated by roughly one half. Configuration S10, like the hingeless-rotor S08, had neutral or reduced gradients in all axes, and the relatively poor no-turbulence ratings resulted in only minor further degradation for the in-turbulence ratings assigned to S10.

The augmented configurations with a significant degradation for at least one pilot were S21, S25, and S26. Recall that S21 and S26 use pitch and roll-rate damping, with neutral stick gradients, plus increased directional aerodynamic stiffness (N_V') and damping for the hingeless- and teetering-rotor configurations, respectively. As was discussed earlier, the characteristics for S21 and S26 are similar to those for S04, although with a slightly higher Dutch roll frequency. Pilot G, the pilot who significantly down-rated these two configurations with turbulence compared with no turbulence, actually gave them and S04 the same rating (inadequate) with turbulence (PR = 7) — the difference is that he rated them significantly better than S04 for no turbulence, probably because of the enhanced turn-following capability. The important point is that although increasing the weathercock directional stiffness is beneficial for turn-following performance, turbulence can stir up the pitch and roll axes through coupling if rate-damping-only is used, and for at least one pilot this was a significantly more difficult situation.

Of the 25 evaluations of the attitude augmented configurations (S24, S25, S27, S28, S30, S31), only once did turbulence cause a significant change (S25, Pilot K). It is important to note that as has been discussed, the best ratings of the experiment were given to some of these configurations, and the fact that turbulence did not degrade them significantly emphasizes the efficacy of pitch-roll attitude augmentation for the task considered in this experiment. From the standpoint of single-pilot IFR, the results of this experiment imply that this type of augmentation is required to obtain a satisfactory capability in the presence of turbulence.

In summary, the primary influences of the turbulence examined in this experiment were as follows:

1. For the hingeless-rotor static gradient configurations using rate-damping augmentation, turbulence had a significant degrading effect on pilot rating for at least one pilot for most of the configurations, although the aircraft was still, on the average, considered at least marginally adequate ($PR \leq 6.5$).

2. Turn-following augmentation obtained by increasing the aerodynamic directional stiffness also demonstrated a sensitivity of pilot rating to turbulence when rate-damping augmentation was used in pitch and roll.

3. Pitch and roll attitude augmentation was required to obtain ratings of satisfactory ($PR \leq 3.5$) in turbulence. On the average, this type of augmentation resulted in no significant change in pilot rating with turbulence.

Influence of Pilot (All Configurations)

Of the 20 force-feel-ON configurations investigated in this experiment (S01-S11, S21, S24-S31), 11 were evaluated by all four pilots who participated, 17 by at least three, and all 20 by at least two pilots. Because of this sizeable number of interpilot repeats, it is possible to obtain some indication of the consistency among the pilots. Toward this end, plots of each pilot's ratings against those for the same configuration by the other pilots are given in figure 11. Again, ±1 PR is assumed to be a minimum expected spread. Each part of the figure also gives the percentage of ratings that fall within this spread.

As can be seen, the correspondence of Pilot G's ratings with those of the other three pilots is generally worse than the correspondence among that of the three. In fact, if each pilot's ratings for all the force-feel-ON configurations are averaged, it can be seen that Pilot G's average ratings were higher than those of the other three pilots:

Pilot	No turbulence, average	Turbulence, average	Number of evaluations
G	5.2	6.4	24
H	4.4	5.1	26
K	4.2	4.9	24
M	4.0	5.2	11

To obtain an indication of where these differences arise, the difference between the ratings, for each configuration of Pilots G, H, and M and those of Pilot K, are plotted in figure 12. For the hingeless-rotor static configurations (S01-S08), Pilot G's ratings are generally significantly lower than Pilot K's, and, for S01-S06, the other pilots agree with ±1 PR. As was noted in the discussion of the static gradients, Pilot G generally appeared more sensitive to a neutral longitudinal or reduced directional gradient than the other pilots. It is possible that Pilot G was extrapolating more thoroughly to an actual single-pilot situation with these configurations than the other three pilots, but it is not possible to substantiate this speculation within the context of this experiment.

Considering the augmented configurations (S21, S24-S31), on the other hand, it can be seen that the agreement among all four pilots was within ±1 PR for all the configurations, with the exception of the one anomalous evaluation of Configuration S30 by Pilot H (discussed earlier). In the context of this experiment, therefore, it is clear that the three higher levels of augmentation considered tend to reduce the sensitivity of pilot rating to individual pilot preferences or control techniques.

In summary, the influences of pilot on the pilot rating results obtained in this experiment are as follows:

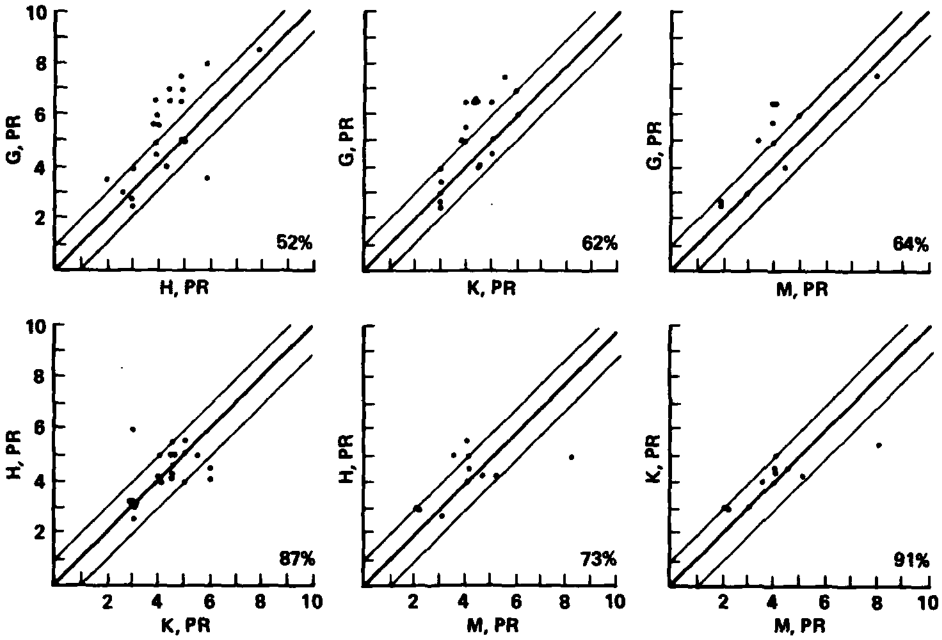


Figure 11.- Interpilot variability: without turbulence.

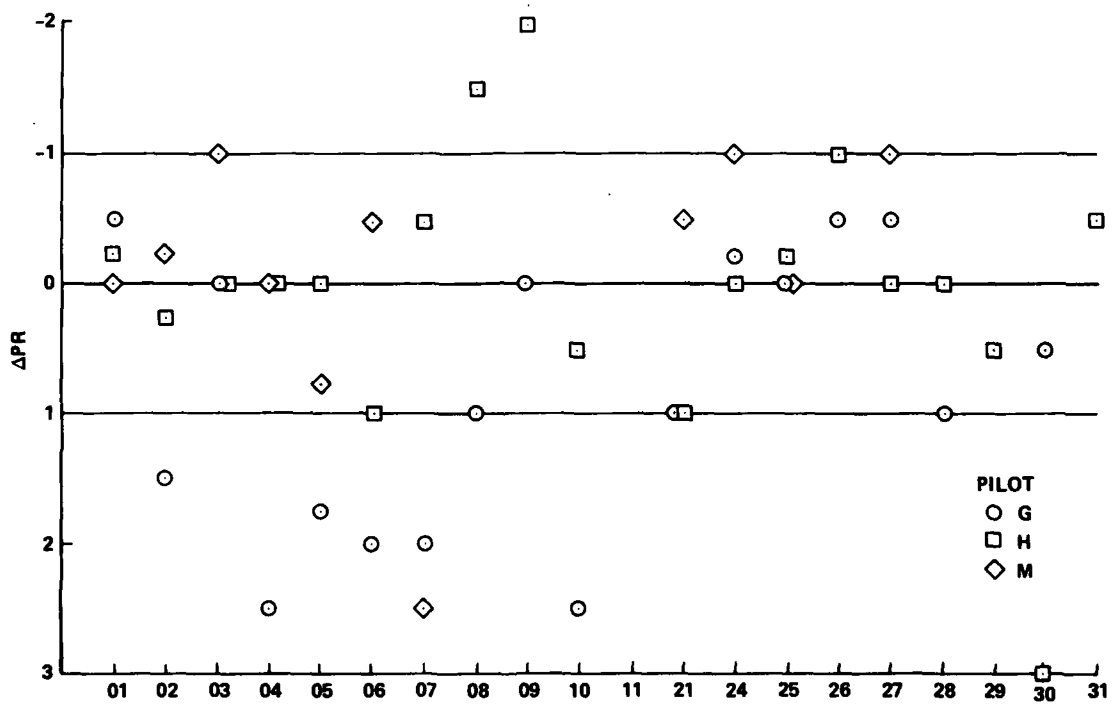


Figure 12.- Change from Pilot K's ratings by Pilots G, H, and M: without turbulence.

1. Pilot G rated the hingeless-rotor static configurations as significantly worse than did the other three pilots. Pilots H, K, and M were in fairly good agreement about these configurations.

2. All four pilots rated the three higher level of augmentation configurations consistently within ±1 PR of each other. It is suggested that an ancillary benefit of such augmentation is to reduce the sensitivity of pilot rating to individual pilot preferences or techniques.

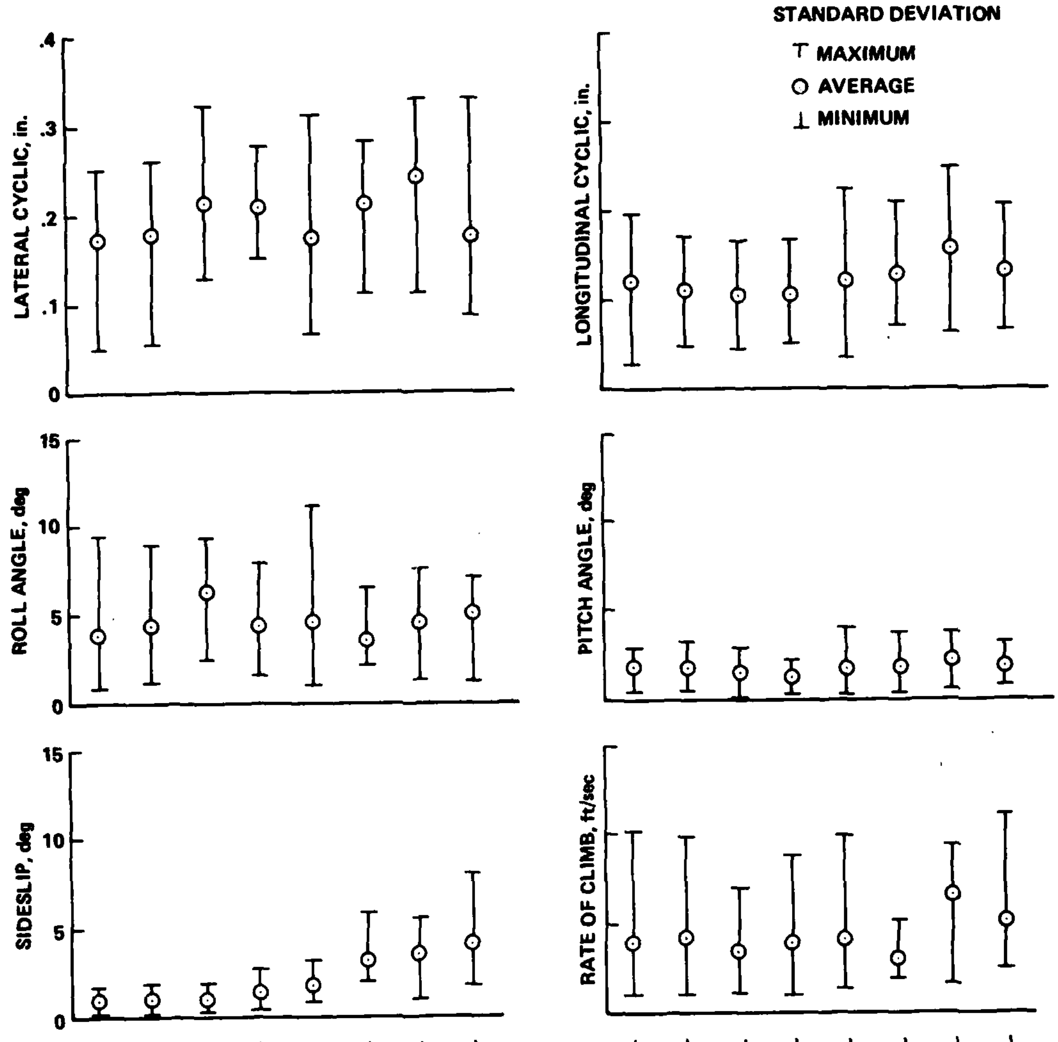
SYSTEM PERFORMANCE AND CONTROL USAGE RESULTS

Measures of pilot-vehicle performance and pilot control usage have often been examined in an attempt to quantify the interactions and trade-offs between performance and workload that are indicated by the Cooper-Harper pilot rating. It is important to understand that, even assuming the "correct" measures may somehow be selected, the relationship between pilot rating and measured performance and workload indices may not be causal except under rigidly controlled and probably unrealistic task scenarios. The discrepancies arise in large part because the pilot rating includes the pilot's judgment of what quality of performance could have been attained, and the performance and workload measures give an indication only of what was actually achieved. In spite of this well-known and often demonstrated incompatibility, however, the use of objective measures of performance and workload in the certification process would be extremely desirable; consequently, such correlations were examined for the data from this experiment also and are discussed in this section.

The first three subsections discuss static gradient configurations with force-feel ON, static gradient configurations with force-feel OFF, and augmentation-type configurations. The discussion in the fourth subsection is also in terms of pilot control usage and pilot-vehicle performance, but the format is different from that of the first three subsections. In the fourth subsection, three configurations were selected (S02, S13 and S25; one from each of the preceding main configuration groups) as a basis for evaluating turbulence effects and pilot differences in control technique across the configuration groups. These three configurations were selected because repeat runs for each were accomplished by three of the four pilots.

Static Gradient Configurations with Force-Feel ON

Cyclic stick displacement, pitch and roll attitude control, rate of climb control, and sideslip control were taken as experimental measures of pilot control usage and pilot-vehicle performance. The standard deviation about mean values was computed for each of these measures over 35-sec time intervals during the descent segment and during the missed-approach segment. Standard deviation (S.D.) values for these segments of several runs were than averaged and plotted along with maximum and minimum S.D. values for each configuration. These values are shown plotted in figure 13 for configurations S01 through S08. Additional values for other measures (directional pedal activity,

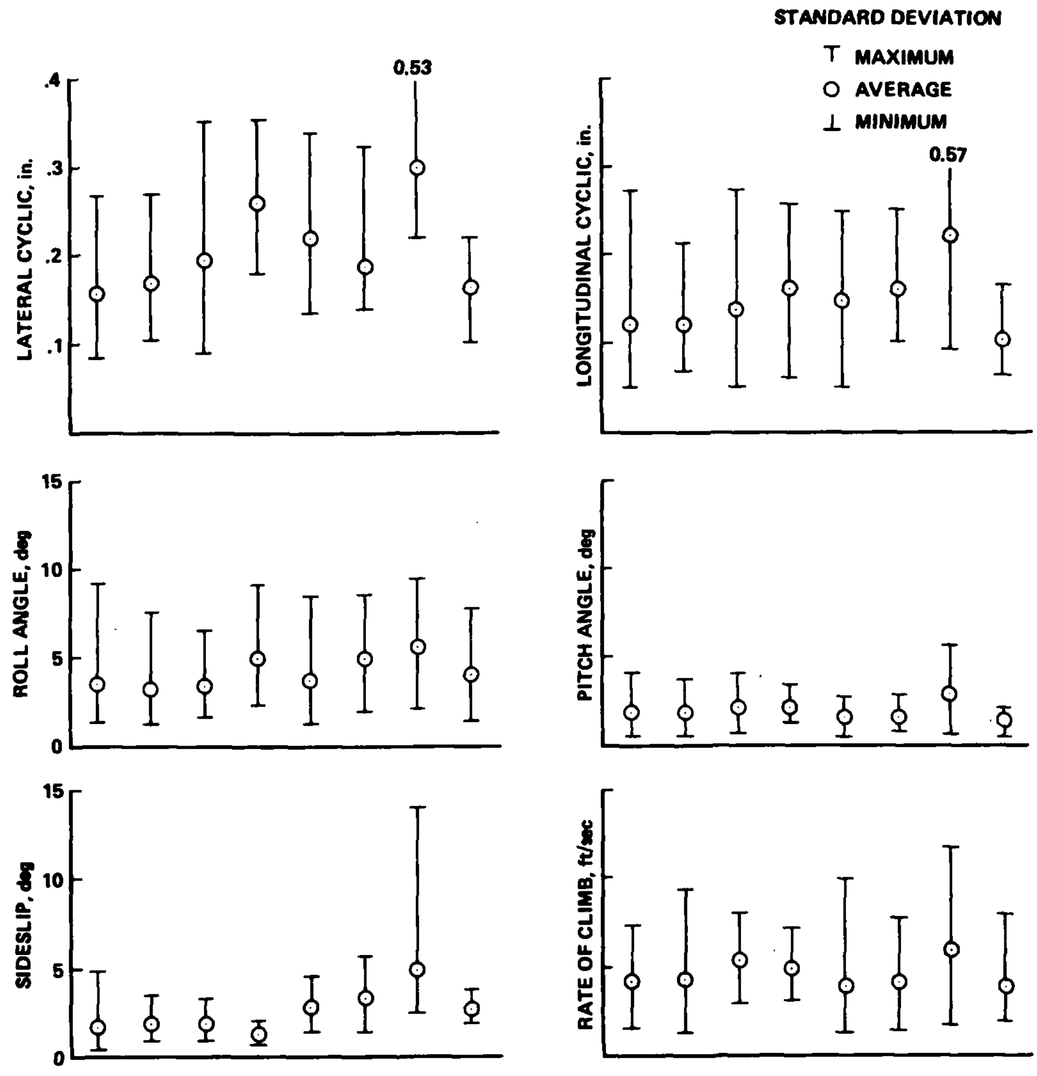


δ_{ES}/V, cm/20 knots	-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01
δ_{AS}/β, cm/15 deg	0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03
δ_{RP}/β, cm/15 deg	-0.72	-0.72	-0.72	-0.72	-0.19	-0.18	-0.19	-0.18
CONFIG. NO.	S01	S02	S03	S04	S05	S06	S07	S08

-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01
0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03
-0.72	-0.72	-0.72	-0.72	-0.19	-0.18	-0.19	-0.18
S01	S02	S03	S04	S05	S06	S07	S08

(a) Without turbulence.

Figure 13.- Control deflection and precision of control, standard deviation (S.D.) values for 35-sec intervals of descent and missed-approach segments: static gradient configurations, force-feel ON.



δ_{ES}/V, cm/20 knots	-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01
δ_{AS}/β, cm/15 deg	0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03
δ_{RP}/β, cm/15 deg	-0.72	-0.72	-0.72	-0.72	-0.19	-0.18	-0.19	-0.18
CONFIG. NO.	S01	S02	S03	S04	S05	S06	S07	S08

-0.64	-0.01	-0.64	-0.01	-0.64	-0.64	-0.01	-0.01
0.57	0.57	-0.01	-0.01	0.57	0.03	0.57	0.03
-0.72	-0.72	-0.72	-0.72	-0.19	-0.18	-0.19	-0.18
S01	S02	S03	S04	S05	S06	S07	S08

(b) With turbulence.

Figure 13.- Concluded.

collective stick activity, and airspeed control) are tabulated in appendix D along with the values which are plotted in the figure. The data are tabulated in a run-by-run format. The tabulated data indicate that on the average the attitude and rate of climb control is poorer and the cyclic stick displacement is greater for the missed-approach segment than for the descent segment. The variation between maximum and minimum S.D. values is also greater for most of the missed-approach segments.

The results for no-turbulence runs are shown in figure 13(a). The left-to-right order of configurations is the same as in figure 1(a) of the preceding section. The trend in the S.D. values of the six measures shown is not entirely consistent with the averaged pilot ratings. This is especially true for longitudinal cyclic, pitch angle, and rate-of-climb variation. The baseline configuration (S01) is actually only third best in these measures. Configuration S06, which has neutral lateral and reduced directional gradients, indicates the best control of rate of climb rather than sixth best; the rate-of climb control of the configurations other than S01 and S06 appears to be consistent with pilot ratings. Considering all six measures, configuration S07 (neutral longitudinal and reduced directional gradient) is clearly the worst configuration; this does agree with the averaged pilot ratings.

The effect of reduced directional static stability on control of sideslip is evident; configurations S05, S06, S07, and S08, all with a reduced directional gradient, show more variation in sideslip than configurations S01, S02, S03, and S04 with a baseline gradient.

In turbulence, considering all six measures (fig. 13(b)), the baseline configuration S01 is second or third best; configuration S07 with neutral longitudinal and reduced directional gradients is again the worst of all eight configurations. A comparison of with-turbulence results with no-turbulence results (figs. 13(b) vs 13(a)), indicates, in general, increased longitudinal and lateral cyclic displacement with turbulence; attitude and flightpath control are at about the same level. One exception is configuration S07 where performance was totally unacceptable due to a loss of control that occurred during one run with this configuration in turbulence. Configuration S08, with neutral longitudinal, neutral lateral and reduced directional gradients, is the best of the eight configurations when judged on the basis of longitudinal cyclic activity, pitch-angle control, and rate-of-climb control; and in fact each measure for this configuration with turbulence is better than the corresponding measure without turbulence. The reason for improvement of configuration S08 compared with configuration S01 is probably that S08 is less sensitive to turbulence than S01 due to smaller values of the derivatives M_u, L'_v, and N'_v used to achieve the reduced gradients for S08. A smaller value for these derivatives means there is less change in the aircraft pitch, roll, and yaw moments due to turbulence in the linear velocity components u and v. However, only one pilot commented on this difference in turbulence sensitivity and the quantitative performance results, on the average, do not vary much between the with-turbulence and without-turbulence conditions.

As in the no-turbulence results, the reduced directional gradient results in poor sideslip control. Recall that the sideslip instrument was not available for normal flight in IMC. The results also show poorer roll-angle control for the aircraft with both neutral longitudinal and neutral lateral gradients than one with either neutral gradient singly — configuration S04 is worse than S02 or S03.

The variations in performance and control usage observed from the six measures for the eight static gradient configurations (S01 through S08) shown in figure 13 may be summarized as follows:

1. Without turbulence, the performance and control usage on the longitudinal axis is not affected by the reduction of longitudinal and lateral gradients to neutral values. There are no significant differences between these configurations (S02, S03, S04) and the baseline configuration (S01). In turbulence, control displacements are higher for configuration S04 with neutral longitudinal and neutral lateral gradients, but the performance is about the same as that without turbulence.

2. On the lateral axis, both with and without turbulence, there is an indication of increased control displacement and degraded performance for configuration S03, with neutral lateral gradient, and for S04, with neutral lateral and longitudinal gradient, when compared with baseline configuration S01 and with configuration S02 with neutral longitudinal gradient.

3. Directionally, there is a definite trend toward degraded sideslip control with the reduced static gradient configurations that is consistent with the pilot ratings given these configurations. This is generally true both with and without turbulence, although greater variations are apparent with turbulence. A maximum value of 14° S.D. in sideslip occurred when control was lost during one S07 run in turbulence.

4. Reduced directional stiffness in combinations with neutral longitudinal or neutral lateral gradients or both (configurations S06, S07, S08) has an adverse effect on no-turbulence longitudinal axis control usage and performance. However, an anomaly exists in the case of longitudinal axis control usage and performance with configuration S08; they are better in turbulence than they are for any of the other configurations.

Static Gradient Configurations with Force-Feel OFF

This subsection discusses the same measures of pilot control usage and pilot-vehicle performance that were discussed in the preceding subsection. The configurations that are evaluated — S13 through S18 — correspond to configurations S01 through S06 in every way except that in this case the control force-feel is turned OFF. As discussed previously, when the force-feel is turned OFF the cyclic stick and directional pedal controls have zero force gradient, centering, and friction so that the pilot must make slight corrective inputs about a reference control position which he maintains — the control will not return by itself to a reference position.

The results for the no-turbulence runs are shown in figure 14(a). On the average, there appears to be very little difference in cyclic deflection or control precision with force-feel OFF as compared with force-feel ON, at least for the measures used in this analysis. It seems, therefore, that the increase in workload reflected in the higher pilot ratings is due to more attention required for instrument scan to permit adequate attitude control. Pilot commentary on most of these configurations supports this contention. Although roll-attitude control is less precise than pitch-attitude control, the average level of each is about the same for all configurations shown. Configuration S17 (reduced directional stiffness) is the worst with regard to control of sideslip and rate of climb.

The with-turbulence results shown in figure 14(b) are similar in trend to the no-turbulence results shown in figure 14(a). There is some increase in control displacement and a slight degradation of performance with turbulence as compared with no turbulence. Again, a degradation in control of sideslip is apparent for those configurations with reduced directional stiffness — S17 and S18.

In summary, the effects of a control-force/displacement relationship of zero (force-feel OFF, configurations S13 through S18) on performance and control usage are as follows.

1. Longitudinally, the control usage and performance difference between the configurations are slight. Configurations S17 and S18 (reduced directional stiffness) are the worst with regard to lateral-directional performance.

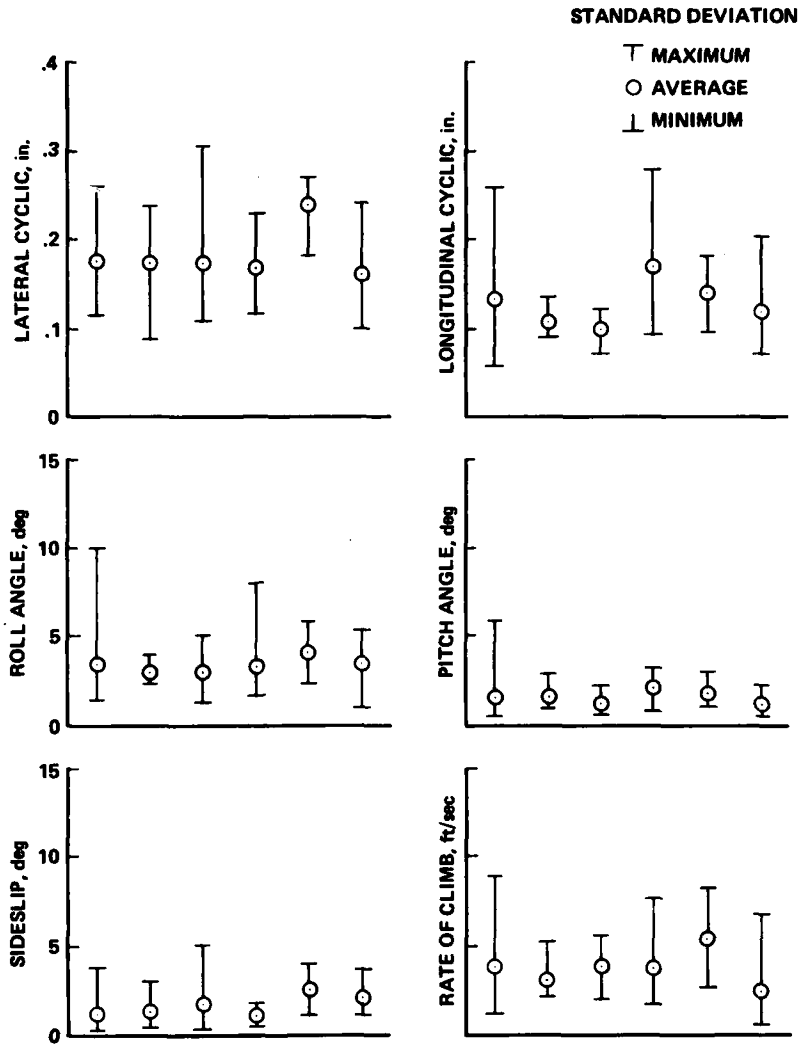
2. On average there is no variation in pitch- or roll-attitude control between the configurations. Roll-attitude control is poorer than pitch-attitude control for all configurations.

3. The performance is somewhat worse with turbulence than without turbulence for these configurations.

Control Augmentation Configurations

A summary of the evaluations of each augmented configuration is given in the following paragraphs. The discussion is grouped according to the rotor type of the baseline configuration — that is, hingeless, teetering, or articulated. The discussion is based on observations of the same six measures as in the preceding subsections: standard deviations of lateral and longitudinal cyclic control displacements, roll and pitch attitude, sideslip, and rate of climb. Average values, maximum values, and minimum values for these measures are shown for each configuration in the accompanying figures.

<u>Hingeless-rotor configurations (S08, S21, S24, S25)</u> — The no-turbulence results are shown in figure 15(a). Except for the attitude command plus directional stiffness system (configuration S24) the cyclic control displacement is reduced by each successive level of augmentation added. In the case of configuration S24, the average and maximum values for lateral cyclic

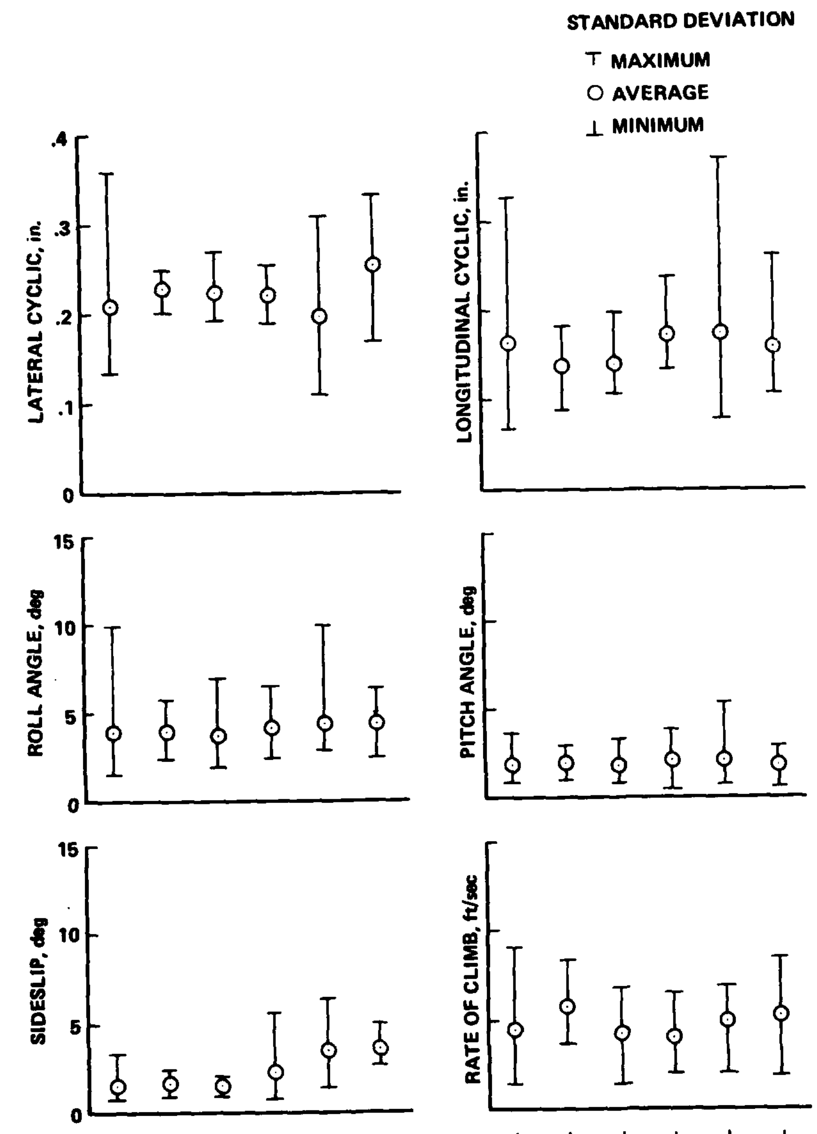


δ_{ES}/V, in./knots	-0.64	-0.01	-0.64	-0.01	-0.64	-0.64
δ_{AS}/β, in./15 deg	0.57	0.57	-0.01	-0.01	0.57	0.03
δ_{RP}/β, in./15 deg	-0.72	-0.72	-0.72	-0.72	-0.19	-0.18
CONFIG. NO.	S13	S14	S15	S16	S17	S18

-0.64	-0.01	-0.64	-0.01	-0.64	-0.64
0.57	0.57	-0.01	-0.01	0.57	0.03
-0.72	-0.72	-0.72	-0.72	-0.19	-0.18
S13	S14	S15	S16	S17	S18

(a) Without turbulence.

Figure 14.- Control deflection and precision of control, standard deviation (S.D.) values for 35-sec intervals of descent and missed-approach segments: static gradient configurations, force-feel OFF.

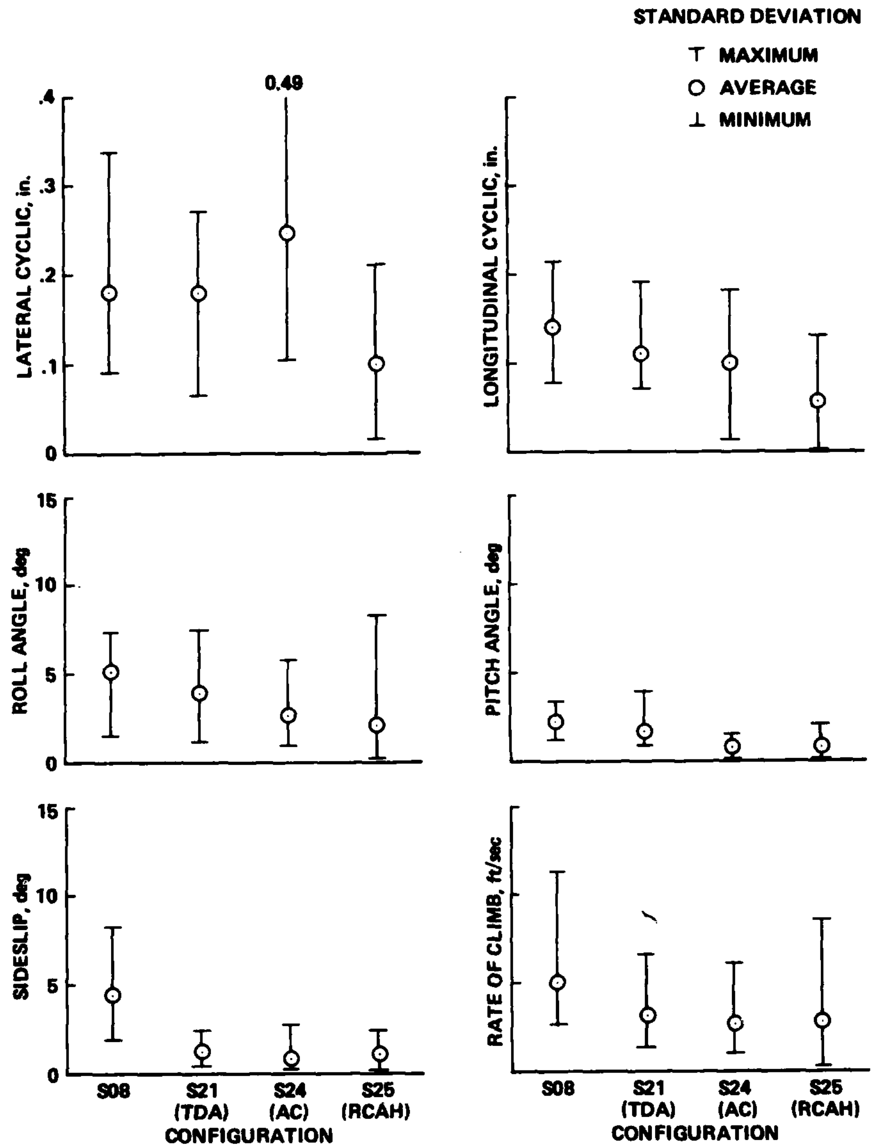


δ_{ES}/V, in./knots	-0.64	-0.01	-0.64	-0.01	-0.64	-0.64
δ_{AS}/β, in./15 deg	0.57	0.57	-0.01	-0.01	0.57	0.03
δ_{RP}/β, in./15 deg	-0.72	-0.72	-0.72	-0.72	-0.19	-0.18
CONFIG. NO.	S13	S14	S15	S16	S17	S18

-0.64	-0.01	-0.64	-0.01	-0.64	-0.64
0.57	0.57	-0.01	-0.01	0.57	0.03
-0.72	-0.72	-0.72	-0.72	-0.19	-0.18
S13	S14	S15	S16	S17	S18

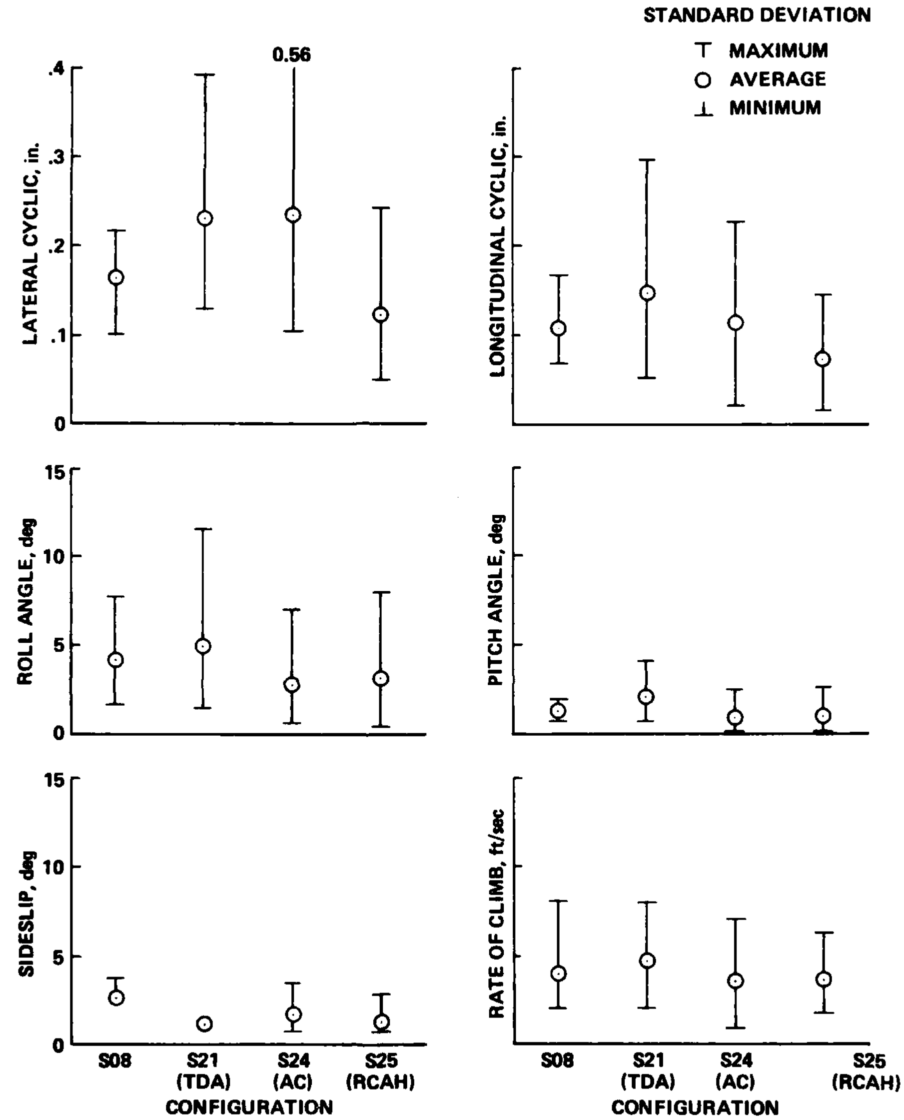
(b) With turbulence.

Figure 14.- Concluded.



(a) Without turbulence.

Figure 15.- Control deflection and precision of control, standard deviation (S.D.) values for 35-sec intervals of descent and missed-approach segments: hingeless rotor augmented configurations.



(b) With turbulence.

Figure 15.- Concluded.

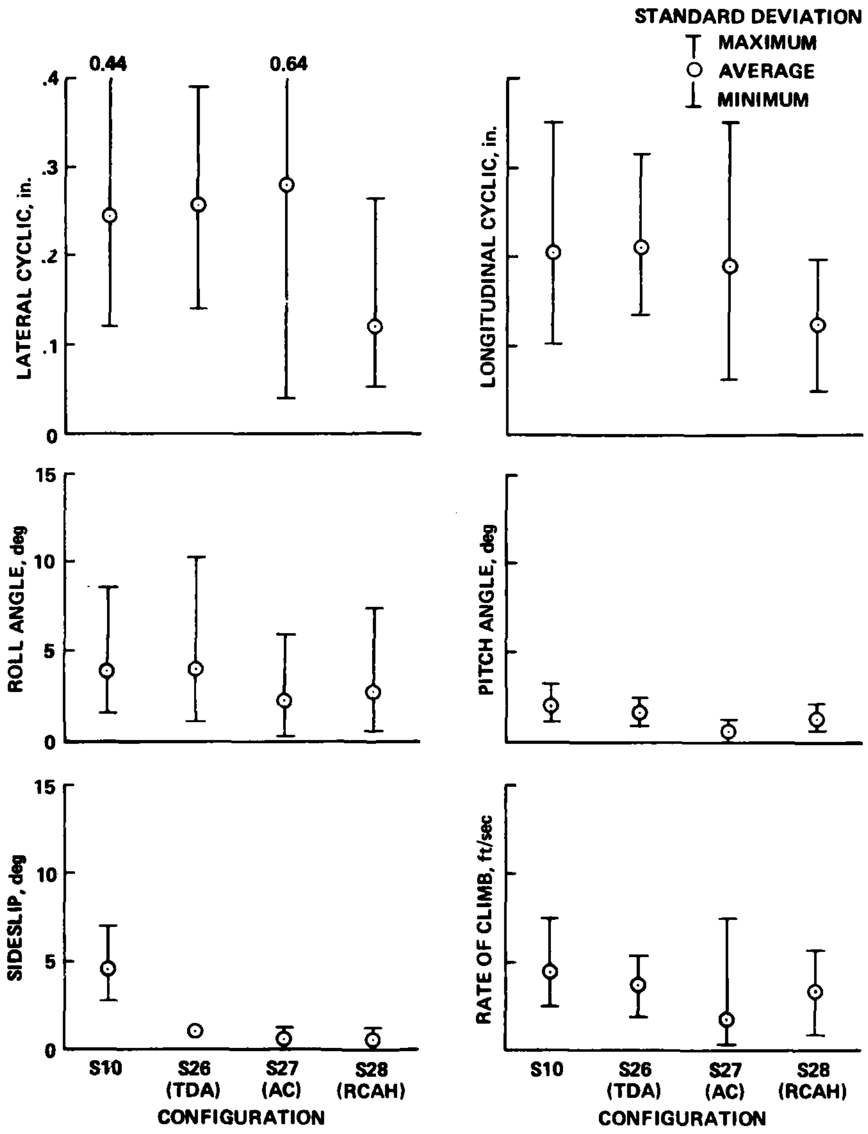
activity are much greater than for the other configurations shown, primarily because of the need to hold a lateral force in turns with an attitude command system (see pilot comments). On the average, the performance in controlling roll and pitch attitude, sideslip, and rate of climb is improved by each level of augmentation added. A large improvement in control of sideslip is achieved by all configurations with the added directional stiffness compared with the baseline configuration (S08).

Figure 15(b) shows inconsistent results in turbulence. The variation in the measured quantities is greater for the with-turbulence case compared with the no-turbulence case. Although there are no clear trends to suggest reduced control usage, or improved performance of the augmented configurations compared with baseline, it should be recalled that in this instance the performance of the baseline configuration (S08) is better with than without turbulence.

<u>Teetering-rotor configurations (S10, S26-S28)</u> — Figure 16(a) shows the results for the teetering-rotor augmented configurations for no-turbulence. The lateral and longitudinal cyclic displacements are significantly less for the rate-command-attitude-hold configuration (S28) than for the other three configurations. Recall that these data are for a 35-sec segment during descent and a 35-sec segment during the missed approach. The reduction in flight control displacement is not, however, necessarily interpreted to mean a reduction in total workload, and in fact it is likely due to the forward loop integrators resulting in pulse-type rather than step-type inputs. The performance of the attitude-command configuration (S27) appears to be the best of the teetering-rotor configurations when considering precision of control of the flight variables shown in the figure. The addition of augmented directional stiffness (configurations S26, S27 and S28) again shows a significant improvement in suppression of sideslip.

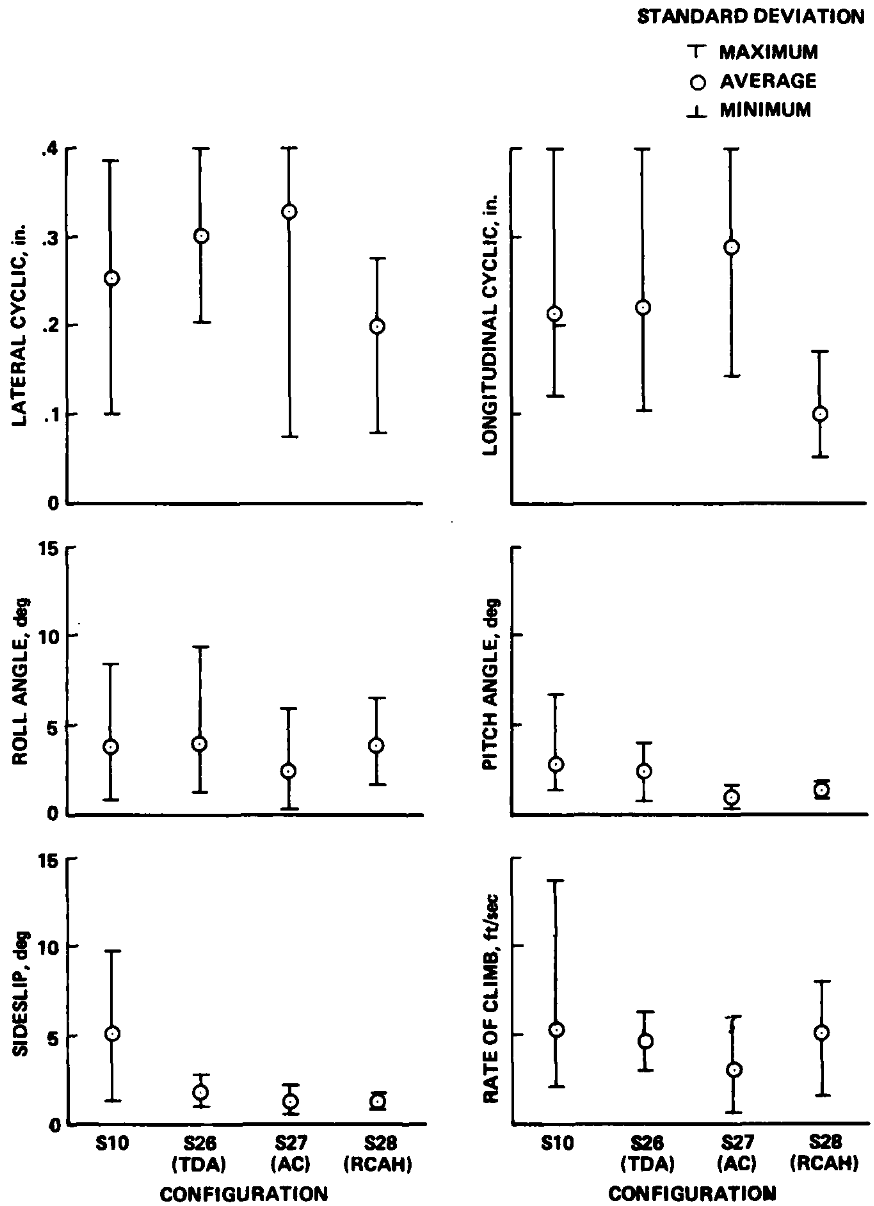
The trends of the with-turbulence results (fig. 16(b)) are similar to those for no-turbulence, although the variation in cyclic displacement is greater for configurations S10, S26, and S27. The cyclic displacement for configuration S28 and performance for all four configurations is nearly the same as for the no-turbulence case. As with the hingeless baseline configuration (S08), the teetering-rotor baseline configuration (S10) performance and control usage measures were not significantly affected by turbulence.

<u>Articulated-rotor configurations (S12, S29, S30, S31)</u> — On average, the performance and control usage of the articulated-rotor augmented configurations (fig. 17) is worse than that of the hingeless- or teetering-rotor configurations (figs. 15 and 16). Poor precision of control is most evident in the sideslip data when compared to the other configurations previously discussed because of the nonlinearity encountered in the sideslip characteristics, as discussed earlier in the design section of this report. Lateral cyclic displacement is higher even for the rate-command-attitude-hold configuration (S31) and is probably due to poor lateral-directional response characteristics at positive sideslip angles. The cyclic displacement for the equivalent hingeless- and teetering-rotor configurations (S25 and S28) was considerably less than that of configuration S31. The control usage was somewhat higher and performance was slightly degraded by the addition of turbulence.



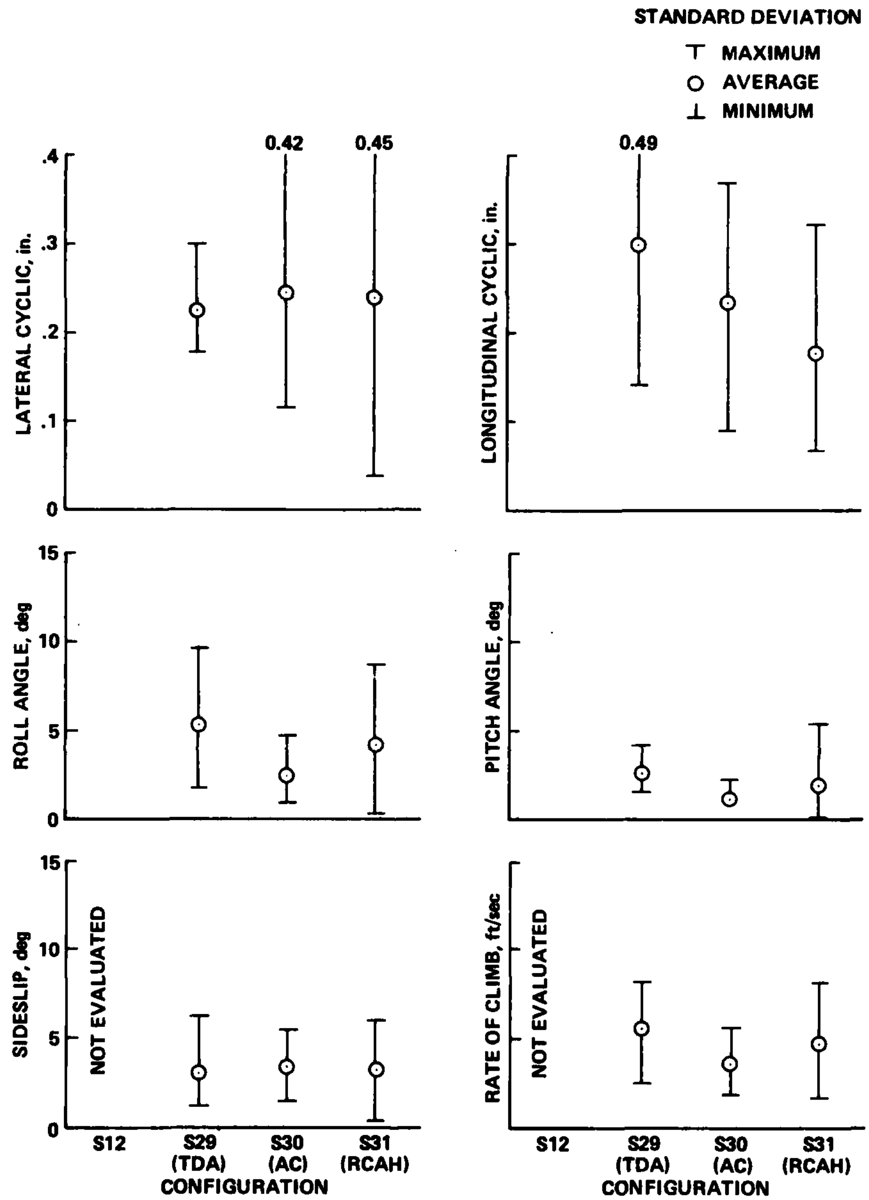
(a) Without turbulence.

Figure 16.- Control deflection and precision of control, standard deviation (S.D.) values for 35-sec intervals of descent and missed-approach segments: teetering rotor augmented configurations.



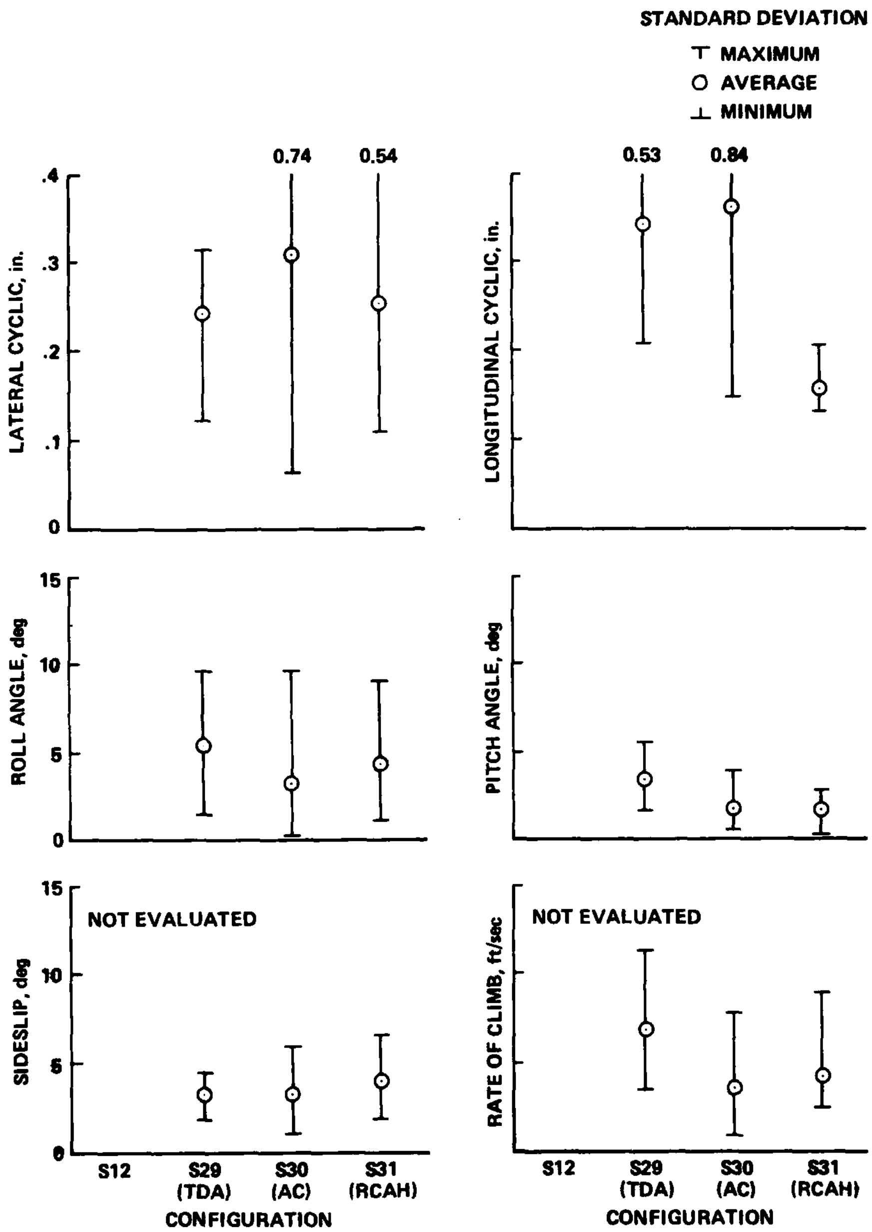
(b) With turbulence.

Figure 16.- Concluded.



(a) Without turbulence.

Figure 17.- Control deflection and precision of control, standard deviation (S.D.) values for 35-sec intervals of descent and missed-approach segments: articulated rotor augmented configurations.



(b) With turbulence.

Figure 17.- Concluded.

Summary of augmentation-type configurations — The performance and control usage results of the augmented configurations are summarized as follows:

1. On average, the performance of the hingeless- and teetering-rotor configurations was improved by the addition of successive levels of SCAS. A large improvement in control of sideslip was achieved by adding turn-following augmentation, which was obtained by increasing the aerodynamic directional stiffness.

2. The greatest reduction in flight control usage as reflected in cyclic displacement was achieved by the addition of rate-command-attitude-hold augmentation.

3. The performance and control usage did not vary significantly between the with-turbulence and no-turbulence conditions.

Turbulence Effects and Pilot Differences in Control Technique (Configurations S02, S13, and S25)

In this subsection, performance and control usage data for hingeless-rotor configurations S02, S13, and S25 are discussed. The data were obtained from evaluations by three of the four pilots (G, H, and K). Pilot M data are not included because he did not conduct repeat runs for each configuration as did the other three pilots. The data are presented in the accompanying figures in a format that differs from that of the three preceding subsections. Cumulative frequency polygons graphically show the percentage or runs from each data-set (36 runs total) that fall within a given range of six measures of control displacement and control precision. The measures are standard deviation values computed during a 35-sec interval of the descent beginning at a point 500 ft past the VOR station. The data are presented as a method for evaluating the cumulative effects of turbulence and for evaluating pilot differences in control technique.

Turbulence effects (configurations S02, S13 and S25; Pilots G, H, and K) — A comparison of cyclic control displacement (figs. 18(a) and 18(b)) shows that the lateral cyclic is more active than the longitudinal cyclic both with and without turbulence. A value on the abscissa of 0.10 in. may be taken as a point of reference for comparison. It is seen that for lateral cyclic, 67% of the data exceeds this value for no turbulence, and 83% exceeds this value with turbulence (an increase in turbulence of 16%). For longitudinal cyclic 39% of the data exceeds the 0.10-in. value without turbulence and 61% exceeds the value with turbulence (an increase of 22% in turbulence). Thus, by this means of determining the cumulative differences it is apparent that flight control usage as reflected by cyclic displacement is increased when in turbulence and that the longitudinal axis is affected more by turbulence than is the lateral axis.

Figures 18(c) and 18(d) show the effect of turbulence on precision of control of pitch attitude and roll attitude, respectively. A comparison of these two figures indicates larger S.D. values (assumed to be less precise)

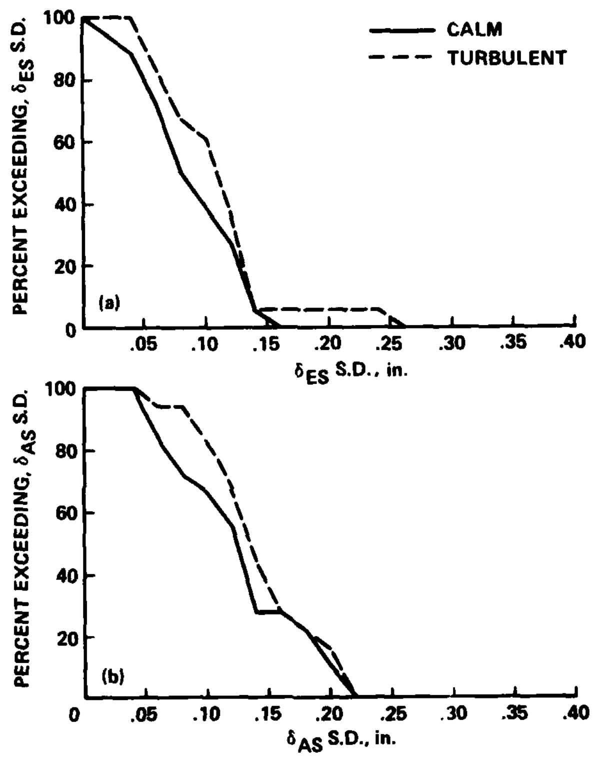


Figure 18.- Effect of turbulence on control deflection and precision of control, standard deviation (S.D.) values from 35-sec intervals of descent segments: configurations S02, S13, and S25; Pilots G, H, and K.

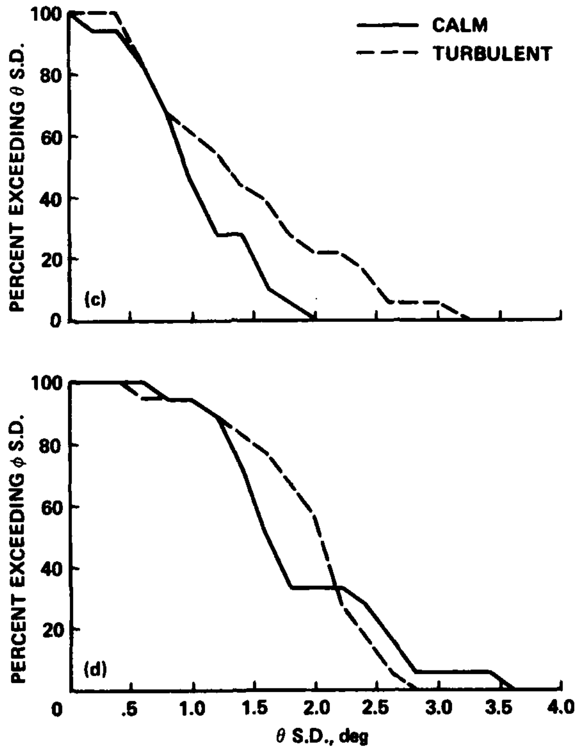


Figure 18.- Continued.

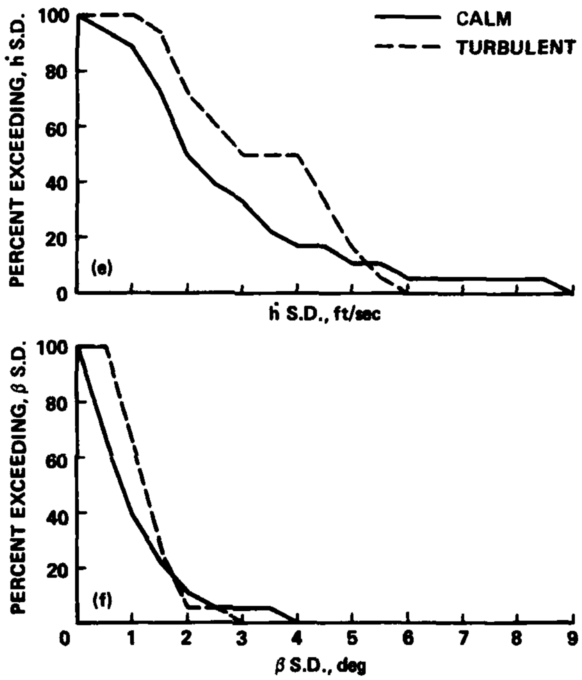


Figure 18.- Concluded.

in roll-attitude control than in pitch-attitude control. On the average (50% level), it can be said that both pitch- and roll-attitude control precision is degraded when in turbulence and that the cumulative effect when considering all the data is greater on the longitudinal axis than on the lateral axis. It can be seen that approximately one third of the roll attitude S.D. values (fig. 18(d)) are greater without than with turbulence. Two factors may account for this anomaly. First, the lateral control sensitivity was too great and not in harmony with the longitudinal control. Second, variations of 3° and 4° in roll are still within the pilots' range of acceptable performance.

The effect of turbulence on control of rate and climb is shown in figure 18(e). It is clear that for this sample of data the rate-of-climb control is degraded by turbulence, even though a small percentage (11%) of the no-turbulence values exceed the with-turbulence values. Sideslip control is also degraded by turbulence, as shown in figure 18(f). Overall, the performance from this data subset was good for both the with-turbulence and no-turbulence conditions. However, directional axis control was slightly degraded by the addition of the low level of turbulence.

Pilot differences in control technique (configurations S02, S13, and S25; Pilots G, H, and K) — Four runs were made by each pilot for each of the three hingeless-rotor configurations — S02, S13, and S25. Two runs each were without turbulence and two runs each were with light turbulence. The effect of pilot differences on cyclic displacement and precision of control is illustrated by the cumulative frequency polygons of figure 19.

A comparison of the data (figs. 19(a) and 19(b)) showing cyclic displacement reflect distinct differences in control techniques between Pilots G, H, and K. Pilot H exercised considerably less cyclic control usage in performing the segment task (descent at 1,000 ft/min after VOR station passage) than Pilots G or K. The differences between Pilots G and K are not as great as those between Pilots H and G; however, differences between pilots are as large or larger than differences with and without turbulence. If 0.1 in. S.D. in longitudinal and lateral cyclic is taken as a reference point, then the percentage values may be read from the figures. A comparison of these values with those read for the same point on figures 18(a) and 18(b) show that the pilot differences are almost always greater than differences due to turbulence. The lateral cyclic displacement is consistently greater than longitudinal cyclic displacement for all pilots, either with or without turbulence.

In comparing precision of control in pitch attitude (fig. 19(c)), differences between the pilots are also apparent. Pilot H's performance is significantly better than that of Pilots K and G. His control technique is effective in obtaining the best performance with the least amount of control usage. Pilot K performance is better than that of Pilot G but he uses more longitudinal cyclic in the process. Differences between pilots in roll-attitude control (fig. 19(d)) are not as apparent, although Pilot H is generally better than the other two. Precision of control in roll attitude is poorer overall than in pitch attitude.

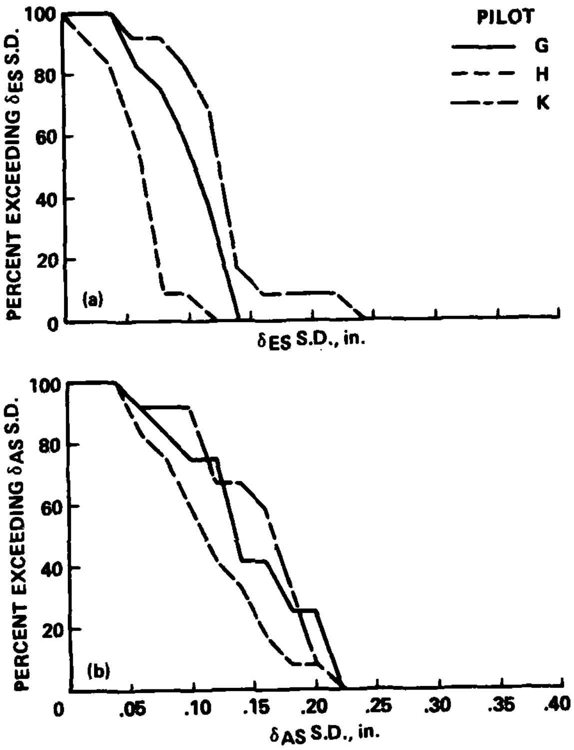


Figure 19.- Pilot differences in control deflection and precision of control, standard deviation (S.D.) values from 35-sec intervals of descent segments: configurations S02, S13, and S25, with and without turbulence.

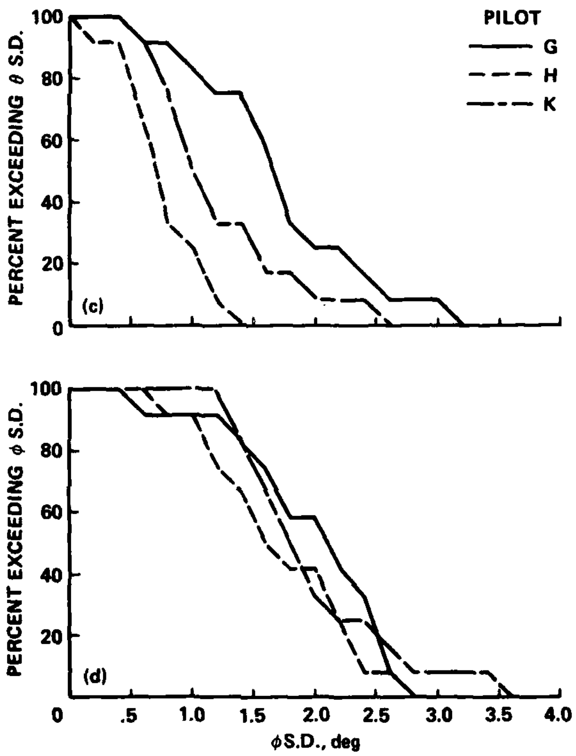


Figure 19.- Continued.

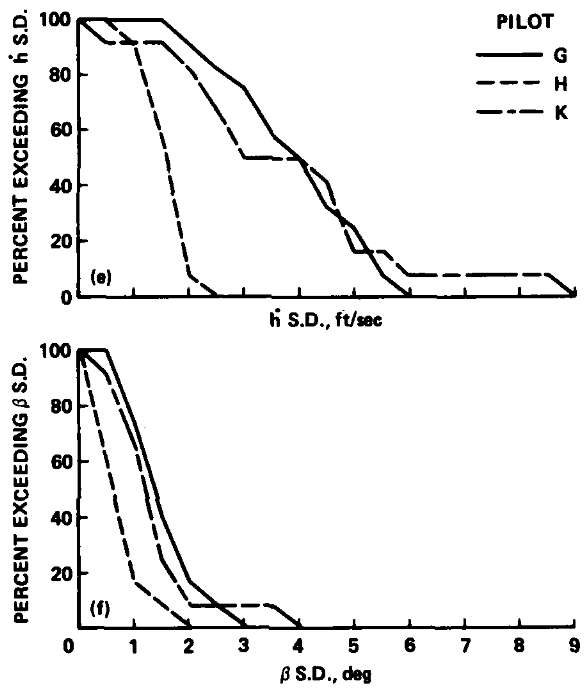


Figure 19.- Concluded.

Pilot H exhibited better control in rate of climb and sideslip than either Pilot G or K (figs. 19(e) and 19(f)). The performance of Pilots G and K is comparable, although Pilot K's results are slightly better for most of the data sampled. The extreme S.D. value of 8.54 ft/sec in rate of climb for Pilot K results from the one run in which the descent after VOR station passage was delayed. This occurred because of a delay in the transition from level flight to a descent rate and not because of large variations about an established rate of climb. The transition to a descent in this case did not begin until 1,500 ft past the VOR station, which is equivalent to a 15-sec delay. The pilot commented following this approach that the workload was low and that the characteristics of the configuration were so good that he did not worry about pilot-vehicle performance (appendix C). Although this may appear to be an anomalous data point, it in fact indicates that easily controllable configurations will frequently exhibit degraded tracking performance measures because of the pilot's knowledge that any steady-state error can be nulled quickly and easily. For this reason it is difficult to define analytical measures that always have a high degree of correlation with pilot workload and pilot-vehicle performance.

Pilot ratings (Pilots G, H, and K) for the three configurations (S02, S13, and S25) are shown in table 9. The first two numbers are no-turbulence ratings, the next two are with-turbulence ratings, and the last is by the average of the four for the configuration. The quantitative data measures, which are not well correlated with the pilot ratings, will be discussed in the following paragraph.

TABLE 9.- PILOT RATINGS — CONFIGURATIONS S02, S13, and S25

Pilot	Configuration		
	S02	S13	S25
G	7, 5, 7, 7 av. 6.5	5.5, 7, 7, 7.5 av. 6.75	3.5, 2.5, 4, 3 av. 3.25
H	5, 4, 5.5, 5 av. 4.87	6, 4.5, 6, 5.5 av. 5.5	2.5, 3, 3, 3 av. 2.87
K	4.5, 4, 6, 5 av. 4.87	5, 4.5, 5.5, 5 av. 5.0	3, 3, 3.5, 4.5 av. 3.5

Pilot H obtained the best precision in all flight variables measured with the least amount of cyclic control usage. He rated configuration S02 and S25 better, on the average (4.87 and 2.87), than did Pilot G. Pilot G achieved the worst precision of the three pilots with considerably more cyclic activity than Pilot H. His average ratings (6.5 and 6.75) for configurations S02 and S13 show that he found their characteristics to be marginally acceptable to unacceptable. Pilot K expended more effort in cyclic control than either Pilot H or G, obtaining a precision better than that of G, but not nearly as good as that of H. Pilot K rated the rate-command-attitude-hold augmented aircraft (average 3.5 for configuration S25) worse than did Pilots G and H, who found it satisfactory. The baseline aircraft with force-feel OFF (configuration S13) was rated better by Pilot K (5.0 average) than by either Pilot G or H (6.75 and 5.5, respective averages). This leads one to believe that Pilot K was not as sensitive as Pilots G and H to the configuration variations of this experiment, at least in terms of pilot ratings. He was at least more tolerant of the worst of these three configurations and willing to expend more effort for mediocre performance.

An attempt was made to develop an analytical relation between control usage, precision of control, and pilot rating. Although much of the quantitative data reflect trends that support the pilot opinion and ratings of the configurations evaluated, as we discussed in the introduction to this section, there is as yet no uniform rule evident that will relate all of the experimental data. For example, as can be seen in the analysis of the limited dataset above, the pilot control technique varies more significantly among the pilots than the ratings do.

It is recommended that work be continued on seeking appropriate sets of parameters to quantify performance and workload. Reliable measures are needed for predicting the probability of exceeding safety margins and thus help in determining the acceptability of experimental configurations. This is necessary to substantiate the handling-qualities data base. Careful attention to the principles laid down by reference 23 is essential in planning and conducting future experiments.

Summary of turbulence effects and pilot differences in control technique — The effects and differences discussed in this subsection may be summarized as follows:

1. The cyclic control displacement is increased and precision of control is degraded by the low level of turbulence experienced. The effects on the longitudinal axis are greater than on the lateral or directional axis. These results are somewhat inconclusive, however, since the largest deviations in sideslip, rate of climb, and roll angle were in no-turbulence conditions.

2. The quantitative data reflect distinct differences in control technique between three pilots (G, H, and K). Differences between pilots are as large or larger than differences between no-turbulence and with-turbulence results. The data do not exhibit good correlation with pilot ratings.

3. It is recommended that work be continued on analytical methods for quantifying performance and workload. To ascertain the validity of the Airworthiness Criteria, reliable measures are needed for predicting the probability that safety margins will be exceeded.

CONCLUSIONS

The piloted simulator experiment described in this report was conducted to investigate the influence of static stability and stability and control augmentation effects on helicopter flying qualities for terminal-area operations in instrument meteorological conditions (IMC). Simulated test configurations were evaluated for a representative IMC VOR approach task in both smooth air and in simulated light turbulence. The experiment was conducted on the six-degree-of-freedom Flight Simulator for Advanced Aircraft ground simulation facility at Ames Research Center. The experimental piloting task permitted full attention to aircraft control. No crosswinds or shears were simulated, and glideslope tracking was not included in the IFR task used.

The following conclusions may be drawn from the results and analyses of this experiment.

Static Control Gradient Considerations

1. For the helicopter configurations examined in this experiment, the longitudinal control position gradient was determined primarily by the velocity stability derivative (M_u) rather than by the angle-of-attack stability (M_α) when no attitude feedback was used. A stable gradient, therefore, does not imply angle-of-attack stability; in fact, it can lead to unstable dynamic oscillations if it is too large, although this situation was not examined. For these configurations, lateral and directional control position gradients were determined primarily by effective dihedral (L'_v) and directional stiffness (N'_v), respectively (also typical with fixed-wing aircraft).

2. For the static gradient configurations (without attitude feedbacks but with a high level of pitch and roll damping plus input decoupling), the best pilot ratings were obtained with all three gradients stable. For these configurations, the ratings were also the most consistent among the pilots for the configuration with all gradients stable; the rating of 4-4½ (adequate but unsatisfactory) is the same as ratings given a comparable configuration in a previous experiment.

3. Neutral longitudinal and lateral position gradients, either singly or together, were rated adequate for the task as evaluated, given good directional characteristics. Neither the average pilot rating nor the longitudinal axis performance and control usage measures was significantly different for these configurations compared to the baseline configuration with all gradients stable. On this basis, there is no justification for excluding neutral longitudinal or lateral position gradients or both, given good directional characteristics, from being acceptable for the full-attention IMC task.

4. Reduced directional stiffness in combination with neutral longitudinal or lateral gradients resulted in degraded control usage and performance measures. The combination of neutral longitudinal and reduced directional gradients was rated the worst of the configurations examined. On this basis,

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A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABI--ETC(U)
SEP 80 J V LEBACQZ, R D FORREST, R M GERDES

UNCLASSIFIED NASA-A-8125 NASA-TM-81188 NL

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the requirement for a minimum level of directional stiffness (through directional gradient or Dutch roll frequency minimums, for example) is justified; the current requirement for the gradient to be only stable may not be sufficiently conservative.

5. For the hingeless-rotor static gradient configurations, using rate damping augmentation, turbulence had a significant degrading effect on pilot rating for at least one pilot for most of the configurations, although the configurations were still, on the average, considered at least marginally adequate (PR $\leq$ 6.5). The cyclic control activity was increased and precision of control was degraded by the low level of turbulence used in the experiment.

6. The lack of control-displacement/force relationship resulted in a significant degradation in pilot ratings when compared with ratings for equivalent configurations with a 0.5 lb/in. relationship for the cyclic stick. However, there were no significant differences in flight-control usage and pilot-vehicle performance between configurations with and without force gradients. A nonzero control-force/displacement relationship permits the pilot to establish trim control positions and avoid inadvertently large inputs, both of which were indicated by pilot comments to be desirable characteristics in IMC flight. In the sense of coupled force-position gradients rather than position-only with no forces, therefore, these results imply the need for force gradients corresponding to the position gradient results: a control-force/displacement relationship appears necessary, at least for the cyclic control. The reference 2 criteria requiring self-centering of the cyclic stick are justifiable on this basis.

7. Flight-control usage and pilot-vehicle performance data for three of the pilots reflected distinct differences in control technique and performance among the pilots. These differences, which were at least as significant as the differences caused by turbulence, did not correlate well with the differences in pilot ratings.

8. With the exception of the baseline configuration with all gradients stable, one pilot generally rated the static-gradient configurations as significantly worse than did the other three pilots, who were in reasonably good agreement for these configurations. It is possible that the one pilot extrapolated more thoroughly to a single-pilot (partial-attention) situation, or that the pilots chose different aspects of the task to concentrate on for different configurations, but it is not possible to substantiate such a speculation within the context of this experiment.

Stability and Control Augmentation Considerations

1. The four types of stability and control augmentation examined in this experiment have varying influences on the control-position gradients. Rate damping affected none of the gradients; turn-following directional augmentation increased the directional gradient in a stable sense; attitude command augmentation increased both the longitudinal and lateral stick gradients; and rate-command-attitude-hold resulted in neutral longitudinal

and lateral stick gradients. The configurations designed to investigate SCAS effects all had inherent (i.e., SCAS-OFF) control position gradients at the lower level investigated: neutral longitudinal and lateral, and reduced directional stiffness.

2. None of the three rotor types was rated satisfactory with the rate damping or turn-following augmentation systems. However, the addition of turn-following resulted in significant improvements in pilot rating and sideslip suppression performance for the teetering- and hingeless-rotor systems.

3. Attitude augmentation in pitch and roll, implemented as either attitude command or rate-command-attitude-hold, was required in conjunction with turn-following directional augmentation to achieve a satisfactory IMC capability. In this experiment, both the teetering- and the hingeless-rotor systems were rated satisfactory with attitude command augmentation. This result corroborates and extends the results of a previous experiment; the implications of both experiments are that use of pitch and roll attitude augmentation is a requirement for a satisfactory helicopter IMC system.

4. No significant differences between attitude-command and rate-command-attitude-hold implementations were shown; the former received marginally better pilot ratings and showed marginally better performance measures, and the latter had the lowest cyclic activity of the SCAS systems investigated. It is important to note that the rate-command-attitude-hold systems involve design selection of additional items such as breakout thresholds and proportional-to-integral gain ratios; it is possible that further tuning could have resulted in equivalent ratings, performance, and workload between the two implementations, but such a speculation cannot be substantiated within the context of this experiment.

5. No general conclusion can be drawn for the articulated-rotor SCAS configurations because of the overriding influence of the directional nonlinearity discussed earlier. Since two of the three pilots rated the attitude command SCAS marginally satisfactory anyway, selection of different empennage characteristics for these configurations would probably have led to results similar to those for the teetering- and hingeless-rotor configurations.

6. The influence of turbulence on pilot rating was negligible for the attitude-augmented configurations. For the rate damping and turn-following augmentation systems, turbulence resulted in a noticeable degradation in pilot rating. The known advantages of attitude augmentation in turbulence-proofing the airframe were corroborated in this experiment.

7. All four pilots rated the three higher level of augmentation configurations consistently with ±1 PR of each other. An ancillary benefit of such augmentation is therefore the reduction of the sensitivity of pilot rating to individual pilot preferences or techniques, again corroborating previous results.

APPENDIX A

DATA SUMMARY

This appendix summarizes the most pertinent details regarding the evaluation configurations.

Table A1 is the master summary, by configuration, of the evaluations conducted in this experiment. For all configurations except S13-S18, the force gradients are related to the tabulated position gradients by:

$$\text{Pitch/roll:} \quad \frac{F_{ES,AS}}{(\ )} \ , \ \left(\frac{\text{lb}}{(\ )}\right) = 0.5\ \frac{\delta_{ES,AS}}{(\ )} \ , \ \left(\frac{\text{in.}}{(\ )}\right)$$

$$\text{Yaw:} \quad \frac{F_{RP}}{(\ )} \ , \ \left(\frac{\text{lb}}{(\ )}\right) = 3.0\ \frac{\delta_{RP}}{(\ )} \ , \ \left(\frac{\text{in.}}{(\ )}\right)$$

For configurations S13-S18, the force gradients were zero regardless of the position gradients.

Table A2 summarizes the eigenvalues and major transfer function numerators of the evaluation configurations. The notation used to indicate the values of the poles and zeroes is:

$\Delta(s)$ characteristic equation

N_j^i transfer function numerator of i response to j input

$K(s + 1/\tau)(s^2 + 2\zeta\omega s + \omega^2) \rightarrow K(1/\tau)(\zeta;\omega)$

The stability and control derivatives of the equation configurations at 60-knot, level flight are give in table A3. The elements of the matrices include the body-axes stability/control derivatives plus lumped gravitational/kinematic terms; for the L' and N' equations, the prime indicates the conventional arranging to eliminate cross-product inertia terms.

Table A4 summarizes the major geometric parameters of the three baseline helicopters used to construct the evaluation configurations. Distances of rotor and surfaces are given from the center of gravity, with positive being aft of and above the c.g.

Table A5 summarizes the influence of sideslip on the eigenvalues of reduced directional gradient configurations for each of the three helicopter rotor types investigated (i.e., teeting, hingeless, and articulated rotors). As is noted in the technical discussion, the articulated rotor configuration exhibited a highly unstable (time-to-double of roughly 6 sec) oscillation at positive sideslips, which is shown in table A5.

Tables A6 through A10 summarize the stability and control feedback and crossfeed gains used to obtain the configuration characteristics.

TABLE A1.- MASTER DATA SUMMARY

Configuration	δ_{ES}/V, in./20 knots	δ_{AS}/β in./15°	δ_{RP}/β in./15°	Type of augmentation	Type of rotor	Pilot	Pilot rating		Run nos.
							NT	T	
S01	-0.64	+0.57	-0.72	Rate	Hingeless	G	4	5½	1-3
						H	4½	5	8-10
						G	4	5	137-139
						K	4½	5	167-169
						H	4	5	186-188
						M	4½	7	296-298
						K	4½	4½	308-311
S02	-0.01	+0.57	-0.72	Rate	Hingeless	G	7	7	4-7
						H	5	5½	11-13
						G	5	7	146-148
						K	4½	6	170-172
						H	4	5	192-194
						M	4	5½	299-301
						K	4	5	357-359
S03	-0.64	-0.01	-0.71	Rate	Hingeless	H	4½	5	24-26
						G	5	7	30-32
						K	5	6	176-179
						M	4	6½	345-347
S04	-0.01	-0.01	-0.71	Rate	Hingeless	G	6½	7	60-63
						H	4	5	94-97
						K	5	5½	250-253
						M	4	4½	374-376
S05	-0.64	+0.57	-0.19	Rate	Hingeless	G	6½	7½	40-42
						H	4	4½	45-47
						G	5½	7½	91-93
						H	4½	5	107-109
						K	4	4	222-225
						K	4½	5	316-318
						M	5	6½	348-350

TABLE A1.- Continued.

Configuration	δ_{ES}/V, in./20 knots	δ_{AS}/β in./15°	δ_{RP}/β in./15°	Type of augmentation	Type of rotor	Pilot	Pilot rating NT	Pilot rating T	Run nos.
S06	-0.64	+0.03	-0.18	Rate	Hingeless	G	6½	7	74-76
						H	5½	5½	125-127
						K	4½	5	259-262
						M	4½	6½	377-379
S07	-0.01	+0.57	-0.19	Rate	Hingeless	G	7½	8	33-36
						H	5	5½	122-124
						K	5½	5½	180-182
						M	8	10	351-353
S08	-0.01	+0.03	-0.18	Rate	Hingeless	H	4½	5	134-136
						G	7	7½	140-142
						K	6	5½	312-314
S09	-0.64	+0.52	-0.33	Rate	Teetering	H	4	4½	54-56
						G	6	6½	87-90
						K	6	6½	232-234
S10	-0.02	+0.02	-0.34	Rate	Teetering	G	8	8½	71-73
						H	6	6½	104-106
						G	7	7½	209-212
						K	5	5	269-271
						H	5	6	324-326
S11	-0.48	+0.66	-0.20	Rate	Articulated	G	8½	9	199-205
						H	8	8	235-239
S13	-0.64 No force-feel	+0.57	-0.72	Rate	Hingeless	H	6	6	15-18
						G	5½	7	110-112
						G	7	7½	143-145
						K	5	5½	173-175
						H	4½	5½	189-191
						M	8	8½	302-304
						K	4½	5	318-320

TABLE A1.- Continued.

Configuration	δ_{ES}/V, in./20 knots	δ_{AS}/β in./15°	δ_{RP}/β in./15°	Type of augmentation	Type of rotor	Pilot	Pilot rating		Run nos.
							NT	T	
S14	−0.01	+0.57	−0.72	Rate	Hingeless	H	6	6	19–23
	No force-feel					G	7	7½	113–115
S15	−0.64	−0.01	−0.71	Rate	Hingeless	H	5½	6	27–29
	No force feel					G	6½	7	116–118
S16	−0.01	−0.01	−0.71	Rate	Hingeless	G	7	8	64–66
	No force-feel					H	5½	5½	98–100
						K	5	5	254–256
S17	−0.64	+0.57	−0.19	Rate	Hingeless	H	6	6	51–53
	No force-feel					G	6½	8	119–121
						K	5	5½	229–231
S18	−0.64	+0.03	−0.18	Rate	Hingeless	G	7	8	80–83
	No force-feel					H	5	5½	131–133
						K	5	5½	263–265
S21	−0.01	0.00	−1.09	Turn-follow	Hingeless	H	5	5½	48–50
						G	5	7	84–86
						K	4	5	226–228
						M	3½	3½	371–373
S24	−0.15	+0.54	−1.09	Attitude command	Hingeless	G	3	3	77–79
						H	3	3	128–130
						G	2½	3	219–221
						K	3	4	266–268
						H	3	3	330–332
						M	2	2	354–356
						K	3	3½	364–367

TABLE A1.- Concluded.

Configuration	δ_{ES}/V, in./20 knots	δ_{AS}/β in./15°	δ_{RP}/β in./15°	Type of augmentation	Type of rotor	Pilot	Pilot rating		Run nos.
							NT	T	
S25	0.0	0.0	-1.09	Rate-command-attitude-hold	Hingeless	G	3½	4½	37-39
						H	2½	3	57-59
						G	2½	3	149-151
						K	3	3½	183-185
						H	3	3	195-197
						M	3	3½	305-307
						K	3	4½	360-363
S26	-0.03	-0.05	-1.94	Turn-follow	Teetering	G	4½	7	213-215
						H	4	5	321-323
						K	5	5½	342-344
S27	-0.18	+0.95	-1.94	Attitude-command	Teetering	G	2½	3	216-218
						H	3	3½	327-329
						K	3	4	368-370
						M	2	2	380-382
S28	0.0	0.0	-1.94	Rate-command-attitude-hold	Teetering	G	4	4	67-70
						H	3	3½	101-103
						K	3	4	272-274
S29	0.00	+0.17	-0.86	Turn-follow	Articulated	H	5	5½	240-243
						K	4½	5½	333-335
S30	-0.26	+0.50	-0.86	Attitude-command	Articulated	G	3½	4	206-208
						H	6	6	244-246
						K	3	3½	339-341
S31	0.0	0.0	-0.86	Rate-command-attitude-hold	Articulated	H	4	4½	247-249
						K	4½	5	336-338

TABLE A2.- EIGENVALUES AND NUMERATOR OF TEST CONFIGURATIONS AT 60-knot, ZERO SIDESLIP, LEVEL FLIGHT

(a) Configurations S01, S13.	
$\Delta(s)$	(10.07)(5.06)(0.73;2.01)(0.001;0.32)(0.81)(0.11)
$N^{u}_{\delta ES}$	-0.60(10.05)(0.095;6.43)(0.73;2.00)(0.87)(0.11)
$N^{w}_{\delta ES}$	-1.55(10.06)(-51.2)(0.73;2.01)(-0.05)(0.61;0.15)
$N^{\theta}_{\delta ES}$	0.82(10.06)(0.73;2.00)(0.81)(-0.006)(0.14)
$N^{u}_{\delta CS}$	0.28(0.83;17.07)(0.72;2.53)(0.47)(-0.20;0.19)
$N^{w}_{\delta CS}$	-7.9(0.83;16.07)(0.72;2.54)(-0.68;0.32)(0.086)
$N^{\theta}_{\delta CS}$	0.03(8.16)(0.69;2.22)(0.62)(0.03)(0.27)
$N^{v}_{\delta AS}$	0.56(-0.28;6.66)(7.50)(4.74)(0.77)(0.09;0.32)
$N^{\phi}_{\delta AS}$	1.85(5.05)(0.74;2.10)(-0.02;0.32)(0.82)
$N^{r}_{\delta AS}$	0.02(20.31)(17.60)(0.48;1.87)(0.81)(-0.03;0.33)
$N^{v}_{\delta RP}$	-1.77(75.3)(42.8)(3.20)(0.81)(0.53;0.41)(-0.008)
$N^{\phi}_{\delta RP}$	-1.04(5.04)(2.74)(2.16)(0.78)(0.013;0.31)
$N^{r}_{\delta RP}$	1.50(0.87;12.43)(1.67)(-1.78)(0.79)(0.02;0.31)
(b) Configurations S02, S14.	
$\Delta(s)$	(10.07)(5.03)(0.73;2.01)(0.09;0.065)(0.80)(0.12)
$N^{u}_{\delta ES}$	-0.60(10.05)(0.10;6.43)(0.73;2.00)(0.11)(0.87)
$N^{w}_{\delta ES}$	-1.55(10.06)(-51.24)(0.73;2.01)(-0.005)(0.63;0.11)
$N^{\theta}_{\delta ES}$	0.82(10.06)(0.73;2.00)(0.82)(0.01)(0.12)
$N^{u}_{\delta CS}$	0.28(0.83;17.04)(0.72;2.54)(0.74)(0.27;0.34)
$N^{w}_{\delta CS}$	-7.9(0.83;16.04)(0.72;2.55)(0.66)(0.19;0.35)
$N^{\theta}_{\delta CS}$	0.03(8.22)(0.68;2.20)(0.58)(0.94;0.11)
$N^{v}_{\delta AS}$	0.56(-0.29;6.61)(7.49)(4.75)(0.72;0.04)(0.76)
$N^{\phi}_{\delta AS}$	1.85(5.02)(0.74;2.09)(0.84)(-0.06;0.15)
$N^{r}_{\delta AS}$	0.02(20.38)(17.50)(0.47;1.87)(0.81)(-0.06;0.15)
$N^{v}_{\delta RP}$	-1.77(75.4)(42.8)(3.18)(0.81)(0.66;0.37)(-0.05)
$N^{\phi}_{\delta RP}$	-1.04(5.01)(2.74)(-2.16)(0.74)(-0.10)(0.16)
$N^{r}_{\delta RP}$	1.50(0.87;12.42)(1.66)(-1.78)(0.75)(0.16)(-0.10)

TABLE A2.- Continued.

(c) Configurations S03, S15.	
$\Delta(s)$	(10.02)(5.06)(0.74;2.06)(0.006;0.32)(0.80)(0.04)
$N^{u}_{\delta ES}$	-0.60(10.01)(0.095;6.43)(0.74;2.05)(0.86)(0.05)
$N^{w}_{\delta ES}$	-1.55(10.02)(-51.2)(0.74;2.06)(-0.06;0.11)(0.08)
$N^{\theta}_{\delta ES}$	0.82(10.02)(0.74;2.05)(0.81)(0.85;0.04)
$N^{u}_{\delta CS}$	0.28(0.83;17.4)(0.72;2.19)(-0.39;0.73)(0.42)
$N^{w}_{\delta CS}$	-7.9(0.83;16.4)(0.71;2.19)(-0.33;0.77)(0.40)
$N^{\theta}_{\delta CS}$	0.03(0.82)(0.69;2.24)(0.75)(0.96;0.09)
$N^{v}_{\delta AS}$	0.56(-0.28;6.66)(7.50)(4.74)(0.78)(0.07;0.33)
$N^{\phi}_{\delta AS}$	1.85(5.05)(0.74;2.10)(-0.01;0.32)(0.81)
$N^{r}_{\delta AS}$	0.023(20.30)(17.60)(0.48;1.87)(0.79)(-0.01;0.32)
$N^{v}_{\delta RP}$	-1.77(76.4)(41.3)(3.16)(0.82)(0.90;0.29)(-0.01)
$N^{\phi}_{\delta RP}$	-1.04(5.04)(2.21)(0.72)(-0.007;0.28)(0.22)
$N^{r}_{\delta RP}$	1.50(0.85;12.95)(0.99;0.85)(0.003;0.28)(0.22)

(d) Configurations S04, S16.	
$\Delta(s)$	(10.02)(5.03)(0.74;2.06)(0.51;0.07)(0.79)(-0.0003)
$N^{u}_{\delta ES}$	-0.60(10.01)(0.09;6.43)(0.74;2.05)(0.05)(0.86)
$N^{w}_{\delta ES}$	-1.55(10.02)(-51.2)(0.74;2.06)(0.02)(0.26;0.10)
$N^{\theta}_{\delta ES}$	0.82(10.02)(0.74;2.05)(0.81)(0.06)(0.008)
$N^{u}_{\delta CS}$	0.28(0.83;17.4)(0.71;2.19)(-0.43;0.60)(0.36)
$N^{w}_{\delta CS}$	-7.9(0.83;16.4)(0.71;2.19)(-0.35;0.64)(0.34)
$N^{\theta}_{\delta CS}$	0.03(8.22)(0.69;2.22)(0.66)(0.51;0.10)
$N^{v}_{\delta AS}$	0.56(-0.29;6.61)(4.75)(0.78)(0.24;0.10)(7.49)
$N^{\phi}_{\delta AS}$	1.85(5.02)(0.74;2.10)(0.80)(0.11;0.08)
$N^{r}_{\delta AS}$	0.02(20.39)(17.49)(0.47;1.87)(0.80)(-0.002;0.12)
$N^{v}_{\delta RP}$	-1.7(76.4)(41.3)(3.15)(0.83)(0.97;0.31)(-0.08)
$N^{\phi}_{\delta RP}$	-1.04(5.01)(2.21)(0.71)(0.29)(-0.45;0.06)
$N^{r}_{\delta RP}$	1.50(0.85;12.94)(0.98;0.84)(0.33)(-0.43;0.08)

TABLE A2.- Continued.

(e) Configurations S05, S17.	
$\Delta(s)$	(10.06)(5.05)(2.58)(0.76)(-0.007;0.32)(0.60;0.40)
$N^{u}_{\delta ES}$	-0.60(10.04)(0.09;6.43)(2.59)(0.58;0.40)(0.82)
$N^{w}_{\delta ES}$	-1.55(-51.2)(10.05)(2.57)(0.49;0.40)(-0.08)(0.16)
$N^{\theta}_{\delta ES}$	0.82(10.05)(2.59)(0.77)(-0.006)(0.57;0.42)
$N^{u}_{\delta CS}$	0.28(0.83;17.09)(0.92;1.96)(0.82)(0.15;0.51)
$N^{w}_{\delta CS}$	-7.9(0.83;16.1)(0.91;1.97)(-0.76)(0.13;0.53)
$N^{\theta}_{\delta CS}$	0.03(8.14)(2.38)(0.94)(0.69;0.43)(-0.06)
$N^{v}_{\delta AS}$	0.56(-0.30;6.59)(7.52)(5.0)(0.79)(-0.02;0.32)
$N^{\phi}_{\delta AS}$	1.85(5.04)(2.57)(-0.08;0.34)(0.97;0.70)
$N^{r}_{\delta AS}$	0.02(0.99;18.87)(0.70;1.04)(0.84)(-0.10;0.35)
$N^{v}_{\delta RP}$	-1.77(75.3)(42.8)(3.20)(0.81)(0.53;0.41)(-0.007)
$N^{\phi}_{\delta RP}$	-1.04(5.04)(2.74)(-2.16)(0.77)(0.02;0.31)
$N^{r}_{\delta RP}$	1.50(0.87;12.43)(1.67)(-1.78)(0.79)(0.02;0.31)

(f) Configurations S06, S18.	
$\Delta(s)$	(10.05)(5.04)(2.50)(-0.01;0.32)(0.72)(0.57)(0.03)
$N^{u}_{\delta ES}$	-0.60(10.02)(0.09;6.43)(2.52)(0.80)(0.03)(0.53)
$N^{w}_{\delta ES}$	-1.55(-51.2)(10.04)(2.49)(0.47)(-0.35;0.14)(0.18)
$N^{\theta}_{\delta ES}$	0.82(10.04)(2.51)(0.75)(0.52)(-0.006)(0.06)
$N^{u}_{\delta CS}$	0.28(0.83;17.03)(2.76)(-0.43;0.69)(0.65)(0.32)
$N^{w}_{\delta CS}$	-7.9(0.83;16.05)(2.77)(-0.37;0.73)(0.66)(0.27)
$N^{\theta}_{\delta CS}$	0.03(8.11)(2.41)(0.93;0.83)(0.29;0.08)
$N^{v}_{\delta AS}$	0.56(-0.30;6.59)(7.52)(4.96)(0.77)(0.005;0.31)
$N^{\phi}_{\delta AS}$	1.85(5.04)(2.57)(-0.009;0.32)(0.72)(0.59)
$N^{r}_{\delta AS}$	0.02(0.99;18.87)(0.71;1.02)(0.77)(-0.02;0.33)
$N^{v}_{\delta RP}$	-1.77(75.3)(42.9)(3.02)(0.82)(0.88;0.31)
$N^{\phi}_{\delta RP}$	-1.04(5.04)(1.06)(-0.40)(0.09;0.37)(0.69)
$N^{r}_{\delta RP}$	1.50(0.87;12.25)(0.99;0.68)(-0.34)(0.08;0.36)

TABLE A2.- Continued.

(g) Configuration S07.	
$\Delta(s)$	(10.06)(5.02)(2.58)(0.60;0.40)(0.17;0.09)(0.75)
$N^{u}_{\delta ES}$	-0.60(10.04)(0.09;6.43)(2.59)(0.59;0.40)(0.82)
$N^{w}_{\delta ES}$	-1.55(-51.2)(10.05)(2.57)(0.57;0.40)(0.10;0.08)
$N^{\theta}_{\delta ES}$	0.82(10.05)(2.59)(0.76)(0.01)(0.59;0.41)
$N^{u}_{\delta CS}$	0.28(0.83;17.07)(0.91;1.97)(-0.92)(0.23;0.52)
$N^{w}_{\delta CS}$	-7.9(0.83;16.07)(0.91;1.98)(-0.88)(0.22;0.53)
$N^{\theta}_{\delta CS}$	0.03(8.19)(2.41)(0.65)(0.03)(0.77;0.43)
$N^{v}_{\delta AS}$	0.56(-0.31;6.55)(7.51)(4.96)(0.77)(0.08;0.05)
$N^{\phi}_{\delta AS}$	1.85(5.02)(2.57)(0.99;0.68)(-0.07;0.13)
$N^{r}_{\delta AS}$	0.02(0.99;18.86)(0.70;1.04)(0.80)(-0.11;0.17)
$N^{v}_{\delta RP}$	-1.77(75.4)(42.8)(3.18)(0.79)(0.71;0.32)(-0.002)
$N^{\phi}_{\delta RP}$	-1.04(5.01)(2.74)(-2.16)(0.77)(0.04)(-0.01)
$N^{r}_{\delta RP}$	1.50(0.87;12.42)(1.65)(-1.78)(0.79)(0.05)(-0.02)

(h) Configuration S08.	
$\Delta(s)$	(10.05)(5.02)(2.50)(-0.02;0.11)(0.68)(0.61)(0.04)
$N^{u}_{\delta ES}$	-0.60(10.02)(0.09;6.43)(2.52)(0.81)(0.03)(0.52)
$N^{w}_{\delta ES}$	-1.55(10.04)(-51.2)(2.49)(0.49)(-0.06;0.10)(0.07)
$N^{\theta}_{\delta ES}$	0.82(10.04)(2.51)(0.76)(0.50)(-0.03)(0.09)
$N^{u}_{\delta CS}$	0.28(0.83;17.01)(2.76)(0.65)(-0.47;0.55)(0.24)
$N^{w}_{\delta CS}$	-7.9(0.83;16.02)(2.77)(-0.39;0.59)(0.66)(0.20)
$N^{\theta}_{\delta CS}$	0.03(8.16)(2.42)(0.89;0.77)(-0.05;0.06)
$N^{v}_{\delta AS}$	0.56(-0.31;6.55)(7.52)(4.96)(0.76)(0.05)(-0.04)
$N^{\phi}_{\delta AS}$	1.85(5.02)(2.56)(0.76)(0.52)(0.34;0.06)
$N^{r}_{\delta AS}$	0.02(0.99;18.86)(0.71;1.03)(0.77)(-0.03;0.14)
$N^{v}_{\delta RP}$	-1.77(75.4)(42.8)(3.01)(0.81)(0.43)(0.16)(-0.07)
$N^{\phi}_{\delta RP}$	-1.04(5.02)(1.03)(0.73)(-0.41)(0.16;0.24)
$N^{r}_{\delta RP}$	1.50(0.87;12.23)(0.98;0.69)(-0.36)(0.17;0.23)

TABLE A2.- Continued.

(i) Configuration S09.

$\Delta(s)$	(9.91)(4.93)(2.71)(1.41)(0.02;0.22)(0.87;0.25)
$N^{u}_{\delta ES}$	-2.22(9.87)(0.18;2.42)(2.72)(1.38)(0.87;0.26)
$N^{w}_{\delta ES}$	-6.35(9.88)(2.71)(6.15)(0.31)(-0.11)(0.62;0.22)
$N^{\theta}_{\delta ES}$	0.42(9.88)(2.72)(1.32)(-0.008)(0.86;0.27)
$N^{u}_{\delta CS}$	0.53(0.98;10.38)(-7.8)(0.95;1.31)(0.37)(-0.23)
$N^{w}_{\delta CS}$	-9.77(0.98;10.04)(-8.34)(0.98;1.26)(0.38)(-0.24)
$N^{\theta}_{\delta CS}$	0.008(8.08)(6.48)(2.70)(0.13)(0.90;0.25)
$N^{v}_{\delta AS}$	1.46(697)(2.72)(1.33)(0.79;0.34)(-0.08)(3.71)
$N^{\phi}_{\delta AS}$	0.93(4.94)(2.69)(1.36)(-0.13;0.26)(0.54)
$N^{r}_{\delta AS}$	0.12(0.95;5.99)(0.84;1.76)(0.53;0.62)(-0.25)
$N^{v}_{\delta RP}$	-1.18(0.95;60.6)(2.06)(0.96)(-0.28;0.33)(-0.12)
$N^{\phi}_{\delta RP}$	-0.27(4.94)(-3.12)(2.07)(1.38)(0.50;0.20)
$N^{r}_{\delta RP}$	0.87(0.88;12.58)(-2.48)(0.97;1.37)(0.05;0.19)

(j) Configuration S10.

$\Delta(s)$	(9.86)(4.89)(2.76)(1.41)(0.43)(0.005;0.03)(0.01)
$N^{u}_{\delta ES}$	-2.22(9.81)(0.18;2.42)(2.77)(1.38)(0.004)(0.42)
$N^{w}_{\delta ES}$	-6.35(9.82)(2.77)(6.15)(4.95)(-0.20)(0.32;0.24)
$N^{\theta}_{\delta ES}$	0.42(9.81)(2.78)(1.32)(0.41)(-0.05)(0.08)
$N^{u}_{\delta CS}$	0.53(0.99;10.25)(-6.35)(0.94)(0.79;0.46)(-0.23)
$N^{w}_{\delta CS}$	-9.77(0.99;9.91)(-7.00)(1.09)(0.83;0.40)(-0.24)
$N^{\theta}_{\delta CS}$	0.008(8.27)(5.84)(2.73)(0.41)(0.42;0.02)
$N^{v}_{\delta AS}$	1.46(721)(2.73)(1.34)(0.75;0.38)(-0.12)(3.67)
$N^{\phi}_{\delta AS}$	0.93(4.90)(2.69)(1.37)(0.54)(-0.22;0.16)
$N^{r}_{\delta AS}$	0.12(0.95;5.96)(0.84;1.76)(0.55;0.65)(-0.32)
$N^{v}_{\delta RP}$	-1.18(0.95;60.58)(1.55)(0.44;1.26)(0.15)(-0.12)
$N^{\phi}_{\delta RP}$	-0.27(4.90)(1.45)(-1.36)(-0.26)(0.70;0.40)
$N^{r}_{\delta RP}$	0.87(0.88;12.32)(1.25)(-0.92)(0.69;0.40)(-0.29)

TABLE A2.- Continued.

(k) Configuration S11.	
$\Delta(s)$	(10.09)(0.99;3.09)(0.67;1.89)(0.10;0.18)(0.08)
$N^{u}_{\delta ES}$	-0.85(10.11)(0.18;5.20)(0.71;1.90)(0.94)(0.08)
$N^{w}_{\delta ES}$	-2.19(10.13)(-27.23)(0.70;1.99)(-0.06)(0.6;0.13)
$N^{\theta}_{\delta ES}$	0.64(10.14)(0.71;1.93)(1.01)(0.01)(0.09)
$N^{u}_{\delta CS}$	0.50(252)(18.54)(3.75)(0.20;1.67)(0.26)(-0.31)
$N^{w}_{\delta CS}$	-7.86(252)(19.34)(3.73)(0.19;1.67)(0.26)(-0.30)
$N^{\theta}_{\delta CS}$	-0.05(10.16)(-5.77)(0.72;1.99)(0.98;0.06)
$N^{v}_{\delta AS}$	0.70(137)(-16.94)(0.81;1.87)(0.67;0.35)(-0.15)
$N^{\phi}_{\delta AS}$	1.38(0.99;3.02)(0.70;1.97)(0.05;0.21)
$N^{r}_{\delta AS}$	0.20(0.82;7.23)(0.39;1.96)(0.10;0.18)(1.41)
$N^{v}_{\delta RP}$	-1.3(151)(27.94)(0.81;2.40)(0.86;0.21)(0.002)
$N^{\phi}_{\delta RP}$	0.16(-0.05;6.63)(3.30)(2.33)(0.10;0.20)
$N^{r}_{\delta RP}$	1.95(0.91;8.71)(0.24;5.88)(2.05)(0.10;0.20)

(l) Configuration S12.	
$\Delta(s)$	(10.03)(0.98;3.34)(0.96;1.14)(0.10)(-0.04)(0.009)
$N^{u}_{\delta ES}$	-0.85(10.05)(0.18;5.20)(2.27)(0.05)(0.92;0.78)
$N^{w}_{\delta ES}$	-2.19(-27.23)(10.08)(2.06)(0.79)(-0.12)(0.45;0.19)
$N^{\theta}_{\delta ES}$	0.64(10.08)(2.25)(0.94;0.81)(-0.01)(0.10)
$N^{u}_{\delta CS}$	0.50(251)(18.51)(3.37)(0.53;1.04)(0.25)(-0.24)
$N^{w}_{\delta CS}$	-7.86(251)(19.30)(3.35)(0.51;1.04)(0.26)(-0.23)
$N^{\theta}_{\delta CS}$	-0.05(10.11)(-5.74)(2.16)(0.86)(0.77;0.04)
$N^{v}_{\delta AS}$	-0.70(137)(-16.95)(2.46)(1.13)(0.35)(0.07)(-0.60)
$N^{\phi}_{\delta AS}$	1.38(0.98;3.30)(0.95;1.22)(-0.10;0.12)
$N^{r}_{\delta AS}$	0.20(0.83;7.26)(0.55;1.50)(0.99)(0.14)(-0.10)
$N^{v}_{\delta RP}$	-1.3(151)(27.89)(0.84;2.37)(0.26)(0.07)(-0.01)
$N^{\phi}_{\delta RP}$	0.16(-0.1;3.40)(0.99;2.75)(0.11;0.09)
$N^{r}_{\delta RP}$	1.94(0.87;10.51)(0.05;2.54)(1.95)(0.11;0.09)

TABLE A2.- Continued.

(m) Configuration S21.

$\Delta(s)$	(10.04)(5.03)(0.80;2.53)(0.68;0.07)(0.79)(-0.008)
$N^{u}_{\delta ES}$	-0.60(10.02)(0.09;6.43)(0.80;2.52)(0.86)(0.06)
$N^{w}_{\delta ES}$	-1.55(10.03)(5.12)(0.80;2.53)(-0.18;0.13)(0.13)
$N^{\theta}_{\delta ES}$	0.82(10.03)(0.80;2.52)(0.81)(0.76;0.05)
$N^{u}_{\delta CS}$	0.28(0.82;18.18)(0.75;2.52)(-0.45;0.60)(0.36)
$N^{w}_{\delta CS}$	-7.9(0.82;17.17)(0.75;2.52)(-0.38;0.63)(0.34)
$N^{\theta}_{\delta CS}$	0.03(8.20)(0.77;2.70)(0.62)(0.92;0.08)
$N^{v}_{\delta AS}$	0.56(0.68;11.17)(0.77;3.47)(0.78)(0.72;0.12)
$N^{\phi}_{\delta AS}$	1.85(5.02)(0.80;2.56)(0.78)(-0.02)(0.05)
$N^{r}_{\delta AS}$	-0.04(0.80;8.76)(2.99)(0.77)(-0.94)(0.14)(-0.10)
$N^{v}_{\delta RP}$	-1.77(76.8)(40.6)(3.22)(0.78)(0.48)(0.08)(0.004)
$N^{\phi}_{\delta RP}$	-1.04(5.00)(2.92)(0.78)(-0.16)(0.61;0.26)
$N^{r}_{\delta RP}$	1.50(0.85;13.24)(1.02)(1.02)(0.58;0.27)(-0.17)

(n) Configuration S24.

$\Delta(s)$	(9.43)(0.77;2.61)(3.01)(0.02)(0.86)(0.66)(1.94)
$N^{u}_{\delta ES}$	-0.77(9.42)(0.10;6.4)(0.78;2.58)(0.86)(0.69)
$N^{w}_{\delta ES}$	-2.00(-50.82)(9.43)(0.78;2.58)(0.70)(0.14;0.09)
$N^{\theta}_{\delta ES}$	1.06(9.43)(0.78;2.57)(0.82)(0.02)(0.68)
$N^{u}_{\delta CS}$	0.28(0.81;2.51)(6.82)(0.44;1.43)(1.90)(0.15)
$N^{w}_{\delta CS}$	-7.9(0.81;23.96)(6.81)(0.44;1.44)(1.89)(0.15)
$N^{\theta}_{\delta CS}$	0.03(7.45)(0.76;2.74)(0.02)(0.97;0.73)
$N^{v}_{\delta AS}$	0.47(7.94)(-0.21;6.78)(2.76)(2.76)(0.76)(0.03)
$N^{\phi}_{\delta AS}$	1.56(3.05)(0.79;2.61)(1.92)(0.82)(0.02)
$N^{r}_{\delta AS}$	0.02(20.67)(17.2)(0.45;2.10)(1.44)(0.80)(0.03)
$N^{v}_{\delta RP}$	-1.77(75.55)(42.08)(0.96;1.80)(0.73)(0.73)(0.02)
$N^{\phi}_{\delta RP}$	-1.04(3.02)(1.92)(1.00)(-0.11)(0.65;0.47)
$N^{r}_{\delta RP}$	1.50(0.83;11.92)(0.90;1.0)(0.79;0.42)(-0.08)

TABLE A2.- Continued.

(o) Configuration S25.	
$\Delta(s)$	(9.43)(0.77;2.61)(3.01)(0.02)(0.86)(0.66)(1.94)
$N^{u}_{\delta ES}$	$\{-0.77(9.42)(0.10;6.4)(0.78;2.58)(0.86)(0.69)\} \cdot \frac{(1.27)}{(0)}$
$N^{w}_{\delta ES}$	$\{-2.00(-50.82)(9.43)(0.78;2.58)(0.70)(0.14;0.09)\} \cdot \frac{(1.27)}{(0)}$
$N^{\theta}_{\delta ES}$	$\{1.06(9.43)(0.78;2.57)(0.82)(0.02)(0.68)\} \cdot \frac{(1.27)}{(0)}$
$N^{u}_{\delta CS}$	0.28(0.81;2.51)(6.82)(0.44;1.43)(1.90)(0.15)
$N^{w}_{\delta CS}$	-7.9(0.81;23.96)(6.81)(0.44;1.44)(1.89)(0.15)
$N^{\theta}_{\delta CS}$	0.03(7.45)(0.76;2.74)(0.02)(0.97;0.73)
$N^{v}_{\delta AS}$	$\{0.47(7.94)(-0.21;6.78)(2.76)(2.76)(0.76)(0.03)\} \cdot \frac{(0.67)}{(0)}$
$N^{\phi}_{\delta AS}$	$\{1.56(3.05)(0.79;2.61)(1.92)(0.82)(0.02)\} \cdot \frac{(0.67)}{(0)}$
$N^{r}_{\delta AS}$	$\{0.02(20.67)(17.2)(0.45;2.10)(1.44)(0.80)(0.03)\} \cdot \frac{(0.67)}{(0)}$
$N^{v}_{\delta RP}$	-1.77(75.55)(42.08)(0.96;1.80)(0.73)(0.73)(0.02)
$N^{\phi}_{\delta RP}$	-1.04(3.02)(1.92)(1.00)(-0.11)(0.65;0.47)
$N^{r}_{\delta RP}$	1.50(0.83;11.92)(0.90;1.0)(0.79;0.42)(-0.08)

(p) Configuration S26.	
$\Delta(s)$	(9.85)(4.89)(0.81;2.56)(0.1;0.05)(1.42)(-0.007)
$N^{u}_{\delta ES}$	-2.22(9.80)(0.18;2.41)(0.81;2.65)(1.39)(-0.008)
$N^{w}_{\delta ES}$	-6.35(9.81)(6.15)(0.81;2.67)(-0.45;0.11)(0.09)
$N^{\theta}_{\delta ES}$	0.42(9.80)(0.81;2.65)(1.32)(0.006)(-0.004)
$N^{u}_{\delta CS}$	0.53(0.98;10.77)(-7.56)(1.71)(0.96;0.41)(-0.07)
$N^{w}_{\delta CS}$	-9.77(0.98;10.42)(-8.19)(1.53)(0.97)(0.11)(-0.09)
$N^{\theta}_{\delta CS}$	0.008(8.19)(5.85)(0.82;2.63)(0.01)(-0.007)
$N^{v}_{\delta AS}$	1.46(745)(4.86)(0.81;2.60)(1.30)(0.03)(-0.002)
$N^{\phi}_{\delta AS}$	0.93(4.90)(0.81;2.59)(1.43)(-0.007;0.09)
$N^{r}_{\delta AS}$	0.12(0.89;6.84)(0.59;2.55)(1.24)(0.11)(-0.09)
$N^{v}_{\delta RP}$	-1.18(0.95;60.59)(1.56)(0.45;1.26)(0.02)(-0.02)
$N^{\phi}_{\delta RP}$	-0.27(4.90)(-1.36)(1.45)(-0.28)(0.68;0.43)
$N^{r}_{\delta RP}$	0.87(0.88;12.32)(1.25)(-0.92)(0.68;0.41)(-0.30)

TABLE A2.- Continued.

(q) Configuration S27.	
$\Delta(s)$	(9.15)(0.01)(0.81;2.66)(0.96;2.71)(1.12)(0.65)
$N^{u}_{\delta ES}$	-2.22(9.10)(0.18;2.41)(0.81;2.67)(1.39)(0.64)
$N^{w}_{\delta ES}$	-6.35(9.10)(-6.15)(0.81;2.68)(0.65)(0.04;0.07)
$N^{\theta}_{\delta ES}$	0.42(9.10)(0.81;2.67)(1.33)(0.01)(0.64)
$N^{u}_{\delta CS}$	0.53(0.96;10.79)(-8.95)(0.82;1.63)(1.65)(-0.03)
$N^{w}_{\delta CS}$	-9.77(9.52)(0.95;10.41)(0.83;1.65)(1.63)(0.01)
$N^{\theta}_{\delta CS}$	0.008(0.99;6.73)(0.82;2.63)(0.02)(0.63)
$N^{v}_{\delta AS}$	1.46(703)(0.81;2.58)(4.91)(1.30)(0.76;0.03)
$N^{\phi}_{\delta AS}$	0.93(0.81;2.59)(0.96;2.70)(1.14)(0.01)
$N^{r}_{\delta AS}$	0.12(0.80;7.44)(0.45;2.32)(0.003)(0.98;1.25)
$N^{v}_{\delta RP}$	-1.18(0.95;60.36)(0.30;1.80)(1.41)(0.59)(0.01)
$N^{\phi}_{\delta RP}$	-0.27(0.96;2.70)(-1.36)(1.17)(0.05)(0.26)
$N^{r}_{\delta RP}$	0.87(0.85;11.91)(0.95;1.27)(-0.75)(0.30)(0.05)

(r) Configuration S28.	
$\Delta(s)$	(9.15)(0.01)(0.81;2.66)(0.96;2.71)(1.12)(0.65)
$N^{u}_{\delta ES}$	$\{-2.22(9.10)(0.18;2.41)(0.81;2.67)(1.39)(0.64)\} \cdot \frac{(1.27)}{(0)}$
$N^{w}_{\delta ES}$	$\{-6.35(9.10)(-6.15)(0.81;2.68)(0.65)(0.04;0.07)\} \cdot \frac{(1.27)}{(0)}$
$N^{\theta}_{\delta ES}$	$\{0.42(9.10)(0.81;2.67)(1.33)(0.01)(0.64)\} \cdot \frac{(1.27)}{(0)}$
$N^{u}_{\delta CS}$	0.53(0.96;10.79)(-8.95)(0.82;1.63)(1.65)(-0.03)
$N^{w}_{\delta CS}$	-9.77(9.52)(0.95;10.41)(0.83;1.65)(1.63)(0.01)
$N^{\theta}_{\delta CS}$	0.008(0.99;6.73)(0.82;2.63)(0.02)(0.63)
$N^{v}_{\delta AS}$	$\{1.46(703)(0.81;2.58)(4.91)(1.30)(0.76;0.03)\} \cdot \frac{(0.67)}{(0)}$
$N^{\phi}_{\delta AS}$	$\{0.93(0.81;2.59)(0.96;2.70)(1.14)(0.01)\} \cdot \frac{(0.67)}{(0)}$
$N^{r}_{\delta AS}$	$\{0.12(0.80;7.44)(0.45;2.32)(0.003)(0.98;1.25)\} \cdot \frac{(0.67)}{(0)}$
$N^{v}_{\delta RP}$	-1.18(0.95;60.36)(0.30;1.80)(1.41)(0.59)(0.01)
$N^{\phi}_{\delta RP}$	-0.27(0.96;2.70)(-1.36)(1.17)(0.05)(0.26)
$N^{r}_{\delta RP}$	0.87(0.85;11.91)(0.95;1.27)(-0.75)(0.30)(0.05)

TABLE A2.- Continued.

(s) Configuration S29.	
$\Delta(s)$	(10.06)(0.96;3.43)(0.90;2.16)(0.97;0.03)(-0.01)
$N^{u}_{\delta ES}$	-0.85(10.08)(0.18;5.20)(0.91;2.46)(0.90)(0.02)
$N^{w}_{\delta ES}$	-2.19(10.10)(-27.22)(0.89;2.54)(-0.04)(0.46;0.09)
$N^{\theta}_{\delta ES}$	0.64(10.11)(0.91;2.49)(0.98)(0.04)(0.006)
$N^{u}_{\delta CS}$	0.50(253)(20.44)(3.66)(0.77;1.65)(0.16)(-0.16)
$N^{w}_{\delta CS}$	-7.86(253)(21.20)(3.65)(0.77;1.64)(0.17)(-0.15)
$N^{\theta}_{\delta CS}$	-0.05(10.13)(-5.32)(0.91;2.55)(0.97;0.02)
$N^{v}_{\delta AS}$	0.70(126)(-14.74)(0.93;2.58)(0.77;0.28)(0.10)
$N^{\phi}_{\delta AS}$	1.38(0.96;3.38)(0.89;2.20)(0.12;0.06)
$N^{r}_{\delta AS}$	0.20(0.82;7.80)(0.51;2.25)(1.47)(0.09)(-0.06)
$N^{v}_{\delta RP}$	-1.30(151)(27.89)(0.84;2.37)(0.26)(0.06)(-0.003)
$N^{\phi}_{\delta RP}$	0.16(-0.10;3.40)(0.99;2.75)(0.12;0.09)
$N^{r}_{\delta RP}$	1.95(0.87;10.51)(0.05;2.45)(1.95)(0.12;0.09)

(t) Configuration S30.	
$\Delta(s)$	(9.35)(0.79;3.60)(0.88;2.44)(0.02)(0.70)(0.49)
$N^{u}_{\delta ES}$	-0.85(9.38)(0.18;5.20)(0.91;2.45)(0.93)(0.68)
$N^{w}_{\delta ES}$	-2.19(9.44)(-27.18)(0.90;2.51)(0.72)(0.09;0.08)
$N^{\theta}_{\delta ES}$	0.64(9.45)(0.91;2.47)(1.02)(0.03)(0.67)
$N^{u}_{\delta CS}$	0.50(433)(20.15)(2.85)(0.89;1.73)(0.13)(-0.17)
$N^{w}_{\delta CS}$	-7.86(433)(20.91)(2.84)(0.90;1.73)(0.11)(-0.15)
$N^{\theta}_{\delta CS}$	-0.05(9.47)(-5.32)(0.91;2.54)(0.02)(0.70)
$N^{v}_{\delta AS}$	0.70(126)(-14.74)(0.93;2.65)(0.48)(-0.06)(-0.19)
$N^{\phi}_{\delta AS}$	1.38(0.78;3.54)(0.89;2.50)(0.03)(0.49)
$N^{r}_{\delta AS}$	0.20(0.75;8.23)(0.41;2.33)(1.76)(0.47)(0.04)
$N^{v}_{\delta RP}$	-1.3(151)(27.20)(0.71;2.63)(0.67)(0.50)(0.03)
$N^{\phi}_{\delta RP}$	0.16(-0.17;3.70)(0.76;3.16)(0.03)(0.50)
$N^{r}_{\delta RP}$	1.95(0.83;9.26)(3.66)(0.04;2.63)(0.50)(0.03)

TABLE A2.- Concluded.

(u) Configuration S31.	
$\Delta(s)$	(9.35)(0.79;3.60)(0.88;2.44)(0.02)(0.70)(0.49)
$N^{u}_{\delta ES}$	$\{-0.85(9.38)(0.18;5.20)(0.91;2.45)(0.93)(0.68)\} \cdot \frac{(1.27)}{(0)}$
$N^{w}_{\delta ES}$	$\{-2.19(9.44)(-27.18)(0.90;2.51)(0.72)(0.09;0.08)\} \cdot \frac{(1.27)}{(0)}$
$N^{\theta}_{\delta ES}$	$\{0.64(9.45)(0.91;2.47)(1.02)(0.03)(0.67)\} \cdot \frac{(1.27)}{(0)}$
$N^{u}_{\delta CS}$	0.50(433)(20.15)(2.85)(0.89;1.73)(0.13)(-0.17)
$N^{w}_{\delta CS}$	-7.86(433)(20.91)(2.84)(0.90;1.73)(0.11)(-0.15)
$N^{\theta}_{\delta CS}$	-0.05(9.47)(-5.32)(0.91;2.54)(0.02)(0.70)
$N^{v}_{\delta AS}$	$\{0.70(126)(-14.74)(0.93;2.65)(0.48)(-0.06)(-0.19)\} \cdot \frac{(0.67)}{(0)}$
$N^{\phi}_{\delta AS}$	$\{1.38(0.78;3.54)(0.89;2.50)(0.03)(0.49)\} \cdot \frac{(0.67)}{(0)}$
$N^{r}_{\delta AS}$	$\{0.20(0.75;8.23)(0.41;2.33)(1.76)(0.47)(0.04)\} \cdot \frac{(0.67)}{(0)}$
$N^{v}_{\delta RP}$	-1.3(151)(27.20)(0.71;2.63)(0.67)(0.50)(0.03)
$N^{\phi}_{\delta RP}$	0.16(-0.17;3.70)(0.76;3.16)(0.03)(0.50)
$N^{r}_{\delta RP}$	1.95(0.83;9.26)(3.66)(0.04;2.63)(0.50)(0.03)

TABLE A3.- STABILITY/CONTROL DERIVATIVES OF TEST CONFIGURATIONS
AT 60-knots, ZERO SIDESLIP, LEVEL FLIGHT

Configurations: S01, S13

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.33840E-01	.21073E-01	.26947E 01	-.32199E 02	.17920E-02	.13121E 01	.00000E 00	-.90610E-01
-.55963E-01	-.79720E 00	.10573E 03	-.20192E 00	-.43467E-02	.32679E 01	.96706E 00	-.17277E 00
.15206E-01	.20201E-03	-.50020E 01	.00000E 00	-.24667E-02	-.32486E 00	.00000E 00	.84513E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14787E-01	-.56409E-02	.12326E 01	.60672E-02	-.14396E 00	-.23335E 01	.32185E 02	-.97874E 02
-.15219E-01	-.20442E-02	.22423E 00	.00000E 00	-.68867E-01	-.10022E 02	-.20040E-05	.16326E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.94640E-02	-.90367E-02	.27707E 00	.00000E 00	.40241E-01	.17753E 00	.13454E-04	-.29637E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28214E 00	-.10024E-01	.27880E-01
-.15534E 01	-.79082E 01	.31106E 00	.27982E-01
.82490E 00	.30731E-01	.48891F-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54662E-01	.27122E 00	.55907E 00	-.17737E 01
.52777E-01	.17254E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19963E-01	-.26252E-01	.23236E-01	.15012E 01

TABLE A3.- Continued.

Configurations: S02, S14

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21925E-01	.21077E-01	.26948E 01	-.32199E 02	.17881E-02	.13121E 01	.00000E 00	-.90601E-01
-.26515E-01	-.79728E 00	.10573E 03	-.20192E 00	-.42923E-02	.32679E 01	.96706E 00	-.17277E 00
.39579E-04	.29142E-03	-.50020E 01	.00000E 00	-.24596E-02	-.32487E 00	.00000E 00	.64509E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14644E-01	-.56396E-02	.12326E 01	.60672E-02	-.14396E 00	-.23335E 01	.32105E 02	-.97874E 02
-.12384E-01	-.20395E-02	.22425E 00	.00000E 00	-.68868E-01	-.10022E 02	.00000E 00	.16326E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.98737E-02	-.90353E-02	.27708E 00	.00000E 00	.40240E-01	.17753E 00	.14295E-04	-.29637E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28218E 00	-.10027E-01	.27880E-01
-.15534E 01	-.79087E 01	.31133E 00	.27982E-01
.82490E 00	.30716E-01	.48820E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54665E-01	.27121E 00	.55907E 00	-.17737E 01
.52770E-01	.17248E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19974E-01	-.26244E-01	.23239E-01	.15012E 01

TABLE A3.- Continued.

Configurations: S03, S15

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.33045E-01	.21077E-01	.26948E 01	-.32199E 02	.15621E-02	.13121E 01	.00000E 00	-.84180E-01
-.55882E-01	-.79728E 00	.10573E 03	-.20192E 00	.27438E-02	.32679E 01	.96706E 00	-.37232E 00
.15207E-01	.20142E-03	-.50020E 01	.00000E 00	-.13682E-02	-.32487E 00	.00000E 00	.53165E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14788E-01	-.56396E-02	.12326E 01	.60672E-02	-.13142E 00	-.23335E 01	.32185E 02	-.98232E 02
-.15214E-01	-.20395E-02	.23425E 00	.00000E 00	-.27476E-01	-.10022E 02	.00000E 00	.45001E 00
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.94621E-02	-.90353E-02	.27708E 00	.00000E 00	.40760E-01	.17753E 00	.14295E-04	-.29786E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28218E 00	-.10027E-01	.27860E-01
-.15534E 01	-.79007E 01	.31133E 00	.27982E-01
.82490E 00	.30716E-01	.48890E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54665E-01	.27121E 00	.55907E 00	-.17737E 01
.52770E-01	.17248E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19974E-01	-.26244E-01	.23239E-01	.15012E 01

TABLE A3.- Continued.

Configurations: S04, S16

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21921E-01	.21073E-01	.26947E 01	-.32199E 02	.15674E-02	.13121E 01	.00000E 00	-.84174E-01
-.26569E-01	-.79720E 00	.10573E 03	-.20192E 00	.26623E-02	.32679E 01	.96706E 00	-.37201E 00
.38270E-04	.20201E-03	-.50020E 01	.00000E 00	-.13704E-02	-.32486E 00	.00000E 00	.53167E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14644E-01	-.56409E-02	.12326E 01	.60672E-02	-.13142E 00	-.23335E 01	.32105E 02	-.98232E 02
-.12366E-01	-.20442E-02	.22423E 00	.00000E 00	-.27477E-01	-.10022E 02	-.20040E-05	.45006E 00
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.98799E-02	-.90367E-02	.27707E 00	.00000E 00	.40762E-01	.17753E 00	.13454E-04	-.29765E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28214E 00	-.10024E-01	.27380E-01
-.15534E 01	-.79082E 01	.31106E 00	.27982E-01
.82490E 00	.30731E-01	.48891E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54662E-01	.27122E 00	.55907E 00	-.17737E 01
.52777E-01	.17254E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19963E-01	-.26252E-01	.23236E-01	.15012E 01

TABLE A3.- Continued.

Configurations: S05, S17

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.33845E-01	.21077E-01	.26948E 01	-.32199E 02	.42306E-02	.13121E 01	.00000E 00	-.90601E-01
-.55882E-01	-.79728E 00	.10573E 03	-.20192E 00	-.48628E-02	.32679E 01	.96706E 00	-.17277E 00
.15207E-01	.20142E-03	-.50020E 01	.00000E 00	-.28904E-02	-.32487E 00	.00000E 00	.84509E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14788E-01	-.56406E-02	.12326E 01	.60672E-02	-.10849E 00	-.23335E 01	.32185E 02	-.97874E 02
-.15214E-01	-.20400E-02	.22425E 00	.00000E 00	-.47859E-01	-.10022E 02	.00000E 00	.16326E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.94621E-02	-.90345E-02	.27708E 00	.00000E 00	.10216E-01	.17753E 00	.14295E-04	-.29637E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28218E 00	-.10027E-01	.27880E-01
-.15534E 01	-.79087E 01	.31133E 00	.27982E-01
.82490E 00	.30716E-01	.48890E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54665E-01	.27121E 00	.55907E 00	-.17737E 01
.52770E-01	.17248E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19974E-01	-.26244E-01	.23239E-01	.15012E 01

TABLE A3.- Continued.

Configurations: SQ6, 818

F MATRIX IS

U	W	Q	THETA	V	P	PHI	P
-.33840E-01	.21074E-01	.26947E 01	-.32199E 02	.10283E-02	.13121E 01	.00000E 00	-.90613E-01
-.55963E-01	-.79720E 00	.10573E 03	-.20192E 00	.14942E-02	.32679E 01	.96706E 00	-.17277E 00
.15206E-01	.20227E-03	-.50019E 01	.00000E 00	-.18809E-02	-.32497E 00	.00000E 00	.84513E-01
.00000E 00	.00000E 00	.39955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30034E-01
-.14780E-01	-.56416E-02	.12326E 01	.60672E-02	-.97022E-01	-.23334E 01	.32105E 02	-.97871E 02
-.15222E-01	-.20410E-02	.22419E 00	.00000E 00	-.10014E-01	-.10022E 02	.00000E 00	.16326E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.94642E-02	-.90352E-02	.27707E 00	.00000E 00	.10694E-01	.17753E 00	.00000E 00	[illegible]

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28214E 00	-.10038E-01	.27881E-01
-.15534E 01	-.79079E 01	.31133E 00	.27982E-01
.82490E 00	.30728E-01	.48891E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54663E-01	.27122E 00	.55906E 00	-.17737E 01
.52782E-01	.17251E 00	.13449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19965E-01	-.26244E-01	.23238E-01	.15012E 01

TABLE A3.- Continued.

Configuration: S07

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21925E-01	.21077E-01	.26948E 01	-.32199E 02	.12306E-02	.13121E 01	.00000E 00	-.90601E-01
-.26515E-01	-.79728E 00	.10573E 03	-.20192E 00	-.48628E-02	.32679E 01	.96706E 00	-.17277E 00
.39578E-04	.20142E-03	-.50020E 01	.00000E 00	-.28904E-02	-.32487E 00	.00000E 00	.84509E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14644E-01	-.56406E-02	.12326E 01	.60672E-02	-.10849E 00	-.23335E 01	.32185E 02	-.97874E 02
-.12384E-01	-.20400E-02	.22425E 00	.00000E 00	-.47859E-01	-.10022E 02	.00000E 00	.16326E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.98797E-02	-.90345E-02	.27708E 00	.00000E 00	.10216E-01	.17753E 00	.14295E-04	-.29637E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28218E 00	-.10027E-01	.27880E-01
-.15534E 01	-.79087E 01	.31133E 00	.27932E-01
.82490E 00	.30716E-01	.48890E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54665E-01	.27121E 00	.55907E 00	-.17737E 01
.52770E-01	.17248E 00	.18449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.13974E-01	-.26244E-01	.23239E-01	.15012E 01

TABLE A3.- Continued.

Configuration: S08

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21922E-01	.21073E-01	.26947E 01	-.32199E 02	.10266E-02	.13121E 01	-.05123E-05	-.90613E-01
-.26569E-01	-.79720E 00	.10573E 03	-.20192E 00	.15213E-02	.32679E 01	.96700E 00	-.17277E 00
.38335E-04	.20214E-03	-.50030E 01	.00000E 00	-.18807E-02	-.32487E 00	.14493E-05	.84513E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14644E-01	-.56412E-02	.12326E 01	.50672E-02	-.97023E-01	-.23335E 01	.32185E 02	-.97874E 02
-.12386E-01	-.20414E-02	.22423E 00	.00000E 00	-.10019E-01	-.10022E 02	-.20040E-05	.16325E 01
.00000E 00	.00000E 00	-.18843E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62710E-02
.98790E-02	-.90358E-02	.27707E 00	.00000E 00	.10631E-01	.17754E 00	.14295E-01	-.29637E 01

G-MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60187E 00	.28214E 00	-.10016E-01	.27880E-01
-.15534E 01	-.79083E 01	.31106E 00	.27982E-01
.82490E 00	.30720E-01	.48088E-01	.21245E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.54660E-01	.27121E 00	.55907E 00	-.17737E 01
.52783E-01	.17254E 00	.10449E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.19961E-01	-.26240E-01	.23230E-01	.15012E 01

TABLE A3.- Continued.

Configuration: S09

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.50629E-01	.29283E-01	.22048E 02	-.32176E 02	.69376E-03	-.91970E 00	.00000E 00	-.13678E 00
-.13599E 00	-.12790E 01	.16977E 03	-.12529E 01	-.23238E-01	-.12006E 01	.49248E-01	-.17116E-01
.78469E-02	-.28264E-02	-.50299E 01	.00000E 00	.12417E-03	.14133E 00	.00000E 00	.36501E-02
.00000E 00	.00000E 00	.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.15306E-02
-.20704E-01	-.20842E-02	.54331E 00	.19177E-02	-.80478E-01	-.11820E 02	.32176E 02	-.97249E 02
-.71010E-02	-.29706E-02	.57378E 00	.00000E 00	-.21809E-01	-.10021E 02	.00000E 00	.94404E 00
.00000E 00	.00000E 00	-.59601E-04	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.38939E-01
:11050E-01	-.41478E-02	.58385E 00	.00000E 00	.72840E-02	-.14883E 01	.00000E 00	-.29591E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.22166E 01	.53086E 00	.00000E 00	.30119E-01
-.63518E 01	-.97738E 01	-.31445E-03	-.22012E-02
.41796E 00	.79018E-02	.20289E-05	-.36193E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.22297E 00	-.73559E-01	.14619E 01	-.11823E 01
-.45183E-01	-.33522E-01	.92323E 00	-.29968E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.18056E 00	.37446E-01	.12164E 00	.86530E 00

TABLE A3.- Continued.

Configuration: S10

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.10537E-01	.29280E-01	.22048E 02	-.32176E 02	.69376E-03	-.91970E 00	.00000E 00	-.13678E 00
-.21587E-01	-.12789E 01	.16977E 03	-.12529E 01	-.23222E-01	-.12007E 01	.49248E-01	-.17116E-01
.29842E-03	-.28268E-02	-.50299E 01	.00000E 00	.12408E-03	.14133E 00	.00000E 00	.36499E-02
.00000E 00	.00000E 00	.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.15306E-02
-.18233E-01	-.20855E-02	.54333E 00	.19177E-02	-.53279E-01	-.11820E 02	.32176E 02	-.97249E 02
-.48465E-02	-.29714E-02	.57379E 00	.00000E 00	-.46315E-02	-.10021E 02	.00000E 00	.94403E 00
.00000E 00	.00000E 00	-.59601E-04	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.38939E-01
.12879E-01	-.41479E-02	.58385E 00	.00000E 00	.95475E-02	-.14883E 01	.00000E 00	-.29591E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.22166E 01	.53087E 00	.39307E-04	.30119E-01
-.63519E 01	-.97746E 01	-.31445E-03	-.22012E-02
.41796E 00	.79074E-02	-.42832E-05	-.36193E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.22300E 00	-.73567E-01	.14619E 01	-.11823E 01
-.45200E-01	-.33519E-01	.92325E 00	-.29968E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.18056E 00	.37463E-01	.12165E 00	.86530E 00

TABLE A3.- Continued.

Configuration: S11

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.37865E-01	.21207E-01	.42402E 01	-.32197E 02	.86461E-02	.68482E-01	.00000E 00	-.51176E-01
-.41847E-01	-.80676E 00	.11037E 03	-.44478E 00	-.47096E-02	.61588E 00	.89583E 00	-.71453E-01
.89767E-02	-.39055E-01	-.50206E 01	.00000E 00	-.17233E-02	.28362E 00	.00000E 00	-.79575E-02
.00000E 00	.00000E 00	.99961E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.27823E-01
.33915E-02	-.11584E-02	-.74724E-01	.12380E-01	-.67947E-01	-.34930E 01	.32184E 02	-.99442E 02
-.14016E-02	-.71916E-02	-.14496E 01	.00000E 00	-.31959E-01	-.10001E 02	.00000E 00	-.34665E 00
.00000E 00	.00000E 00	-.36451E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.13814E-01
-.97580E-02	-.37781E-01	.49916E 00	.00000E 00	.35135E-01	-.14749E 01	.00000E 00	-.29297E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.84738E 00	.49687E 00	.43148E-02	-.10692E 00
-.21862E 01	-.78643E 01	.14840E 00	.62212E-01
.63936E 00	-.53021E-01	-.29902E-02	.11019E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.10031E 00	.12060E 00	.70238E 00	-.12967E 01
-.42622E-02	-.81262E-02	.13781E 01	.13043E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.58238E-01	.10790E 00	.20321E 00	.19480E 01

TABLE A3.- Continued.

Configuration: S12

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.25330E-01	.21205E-01	.42402E 01	-.32197E 02	.10054E-01	.68472E-01	.00000E 00	-.51189E-01
-.91477E-02	-.80667E 00	.11037E 03	-.44478E 00	-.27622E-02	.61559E 00	.89581E 00	-.71412E-01
-.44557E-03	-.39054E-01	-.50206E 01	.00000E 00	-.31537E-02	.28366E 00	.00000E 00	-.79205E-02
.00000E 00	.00000E 00	.99961E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.27823E-01
.34335E-02	-.11618E-02	-.74777E-01	.12380E-01	-.38899E-01	-.34930E 01	.32184E 02	-.99442E 02
-.11907E-02	-.71901E-02	-.14496E 01	.00000E 00	-.83946E-02	-.10001E 02	.00000E 00	-.34666E 00
.00000E 00	.00000E 00	-.38450E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.13814E-01
-.84401E-02	-.37777E-01	.49919E 00	.00000E 00	.14500E-01	-.14749E 01	.00000E 00	-.29297E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.84737E 00	.49683E 00	.43036E-02	-.10686E 00
-.21862E 01	-.78637E 01	.14844E 00	.62140E-01
.63936E 00	-.53015E-01	-.29848E-02	.11012E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.10032E 00	.12057E 00	.70238E 00	-.12967E 01
-.42769E-02	-.81384E-02	.13781E 01	.13043E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.58229E-01	.10791E 00	.20321E 00	.19480E 01

TABLE A3.- Continued.

Configuration: S21

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21918E-01	.21074E-01	.26948E 01	-.32199E 02	.19679E-02	.13121E 01	.00000E 00	-.10011E 00
-.26596E-01	-.79720E 00	.10573E 03	-.20191E 00	.30427E-02	.32675E 01	.96705E 00	-.47069E 00
.30270E-04	.20260E-03	-.50020E 01	.00000E 00	-.10647E-02	-.32407E 00	.00000E 00	.26526E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30033E-01
-.14641E-01	-.56408E-02	.12326E 01	.60667E-02	-.15689E 00	-.23335E 01	.32185E 02	-.97201E 02
-.12384E-01	-.20386E-02	.22424E 00	.00000E 00	-.42568E-01	-.10022E 02	.80162E-05	.67236E 00
.00000E 00	.00000E 00	-.18841E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62706E-02
:98765E-02	-.90365E-02	.27707E 00	.00000E 00	.62318E-01	.17752E 00	-.92498E-05	-.39784E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.60200E 00	.28215E 00	-.11251E-01	.27908E-01
-.15537E 01	-.79090E 01	.31024E 00	.28253E-01
.82479E 00	.30697E-01	.47963E-01	.21266E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.63304E-01	.27320E 00	.63654E 00	-.17737E 01
.57865E-01	.17369E 00	.18908E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.27280E-01	-.27909E-01	-.42330E-01	.15012E 01

TABLE A3.- Continued.

Configurations: S24, S25

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.21925E-01	.21073E-01	.26949E 01	-.27731E 02	.19659E-02	.13122E 01	.34949E-01	-.10907E 00
-.26515E-01	-.79723E 00	.10573E 03	.11611E 02	.30698E-02	.32679E 01	-.11747E 00	-.19114E 00
.40625E-04	.20273E-03	-.50020E 01	-.60947E 01	-.10640E-02	-.32487E 00	-.17031E 00	.70443E-01
.00000E 00	.00000E 00	.99955E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.30035E-01
-.14644E-01	-.56402E-02	.12327E 01	.63314E-01	-.15689E 00	-.23335E 01	.30237E 02	-.96699E 02
-.12386E-01	-.20393E-02	.22426E 00	.11381E 01	-.42564E-01	-.10022E 02	-.64265E 01	.23291E 01
.00000E 00	.00000E 00	-.18845E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.62714E-02
.90795E-02	-.90364E-02	.27710E 00	.16778E 00	.62318E-01	.17753E 00	-.80952E-01	-.39575E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.77164E 00	.28212E 00	-.85023E-02	.27882E-01
-.20019E 01	-.79076E 01	.26379E 00	.27982E-01
.10564E 01	.30730E-01	.41435E-01	.21247E-01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.52488E-01	.27122E 00	.47380E 00	-.17737E 01
.95297E-02	.17251E 00	.15635E 01	-.10505E 01
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.26349E-01	-.26230E-01	.19689E-01	.15012E 01

TABLE A3.- Continued.

Configuration: S26

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.18533E-01	.29284E-01	.22049E 02	-.32176E 02	.25225E-02	-.91970E 00	.00000E 00	-.17157E 00
-.21603E-01	-.12790E 01	.16977E 03	-.12529E 01	-.23364E-01	-.12006E 01	.49248E-01	-.14594E-01
.29809E-03	-.28264E-02	-.50299E 01	.00000E 00	-.95718E-04	.14132E 00	.00000E 00	.78259E-02
.00000E 00	.00000E 00	.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.15306E-02
-.18234E-01	-.20852E-02	.54333E 00	.19177E-02	-.12506E 00	-.11820E 02	.32176E 02	-.95881E 02
-.48484E-02	-.29716E-02	.57379E 00	.00000E 00	-.22826E-01	-.10021E 02	.00000E 00	.12908E 01
.00000E 00	.00000E 00	-.59601E-04	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.38940E-01
.12877E-01	-.41407E-02	.58386E 00	.00000E 00	.62083E-01	-.14803E 01	.00000E 00	-.39604E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.22167E 01	.53084E 00	.68787E-04	.30119E-01
-.63518E 01	-.97746E 01	-.15723E-03	-.22012E-02
.41797E 00	.79148E-02	-.99189E-05	-.36193E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.22300E 00	-.73555E-01	.14619E 01	-.11823E 01
-.45199E-01	-.33511E-01	.92324E 00	-.29968E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.18056E 00	.37465E-01	.12164E 00	.86531E 00

TABLE A3.- Continued.

Configurations: S27, S28

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.10533E-01	.29285E-01	.22048E 02	.10214E 01	.25235E-02	-.91962E 00	-.10134E-03	-.17164E 00
-.21603E-01	-.12789E 01	.16977E 03	.93475E 02	-.23364E-01	-.12006E 01	.50689E-01	-.14594E-01
.29788E-03	-.28274E-02	-.50299E 01	-.62503E 01	-.95763E-04	.14131E 00	.20666E-05	.78365E-02
.00000E 00	.00000E 00	.10000E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.15306E-02
-.10235E-01	-.20851E-02	.54328E 00	.20479E 01	-.12506E 00	-.11820E 02	.22282E 02	-.95881E 02
-.48483E-02	-.29712E-02	.57376E 00	.18657E 01	-.22826E-01	-.10021E 02	-.62483E 01	.12908E 01
.00000E 00	.00000E 00	-.59601E-04	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.38939E-01
.12878E-01	-.41478E-02	.58385E 00	.15125E 01	.62083E-01	-.14883E 01	-.82323E 00	-.39604E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.22167E 01	.53087E 00	.98267E-05	.30119E-01
-.63518E 01	-.97748E 01	-.31445E-03	-.22012E-02
.41797E 00	.79112E-02	.67629E-06	-.36195E-02
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.22300E 00	-.73566E-01	.14619E 01	-.11823E 01
-.45197E-01	-.33519E-01	.92324E 00	-.29968E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10057E 00	.37463E-01	.12163E 00	.86530E 00

TABLE A3.- Continued.

Configuration: S29

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.25331E-01	.21205E-01	.42402E 01	-.32197E 02	.73812E-02	.68484E-01	.00000E 00	.41774E-01
-.91477E-02	-.80667E 00	.11037E 03	-.44478E 00	-.12078E-02	.61561E 00	.89581E 00	-.12542E 00
-.44507E-03	-.39055E-01	-.50206E 01	.00000E 00	-.40070E-03	.28366E 00	.00000E 00	-.10372E 00
.00000E 00	.00000E 00	.99961E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.27823E-01
.34353E-02	-.11595E-02	-.74767E-01	.12380E-01	-.71314E-01	-.34930E 01	.32184E 02	-.98314E 02
-.11901E-02	-.71895E-02	-.14496E 01	.00000E 00	-.51335E-02	-.10001E 02	.00000E 00	-.46014E 00
.00000E 00	.00000E 00	-.38451E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.13814E-01
-.84418E-02	-.37778E-01	.49918E 00	.00000E 00	.63198E-01	-.14748E 01	.00000E 00	-.46245E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.84737E 00	.49683E 00	.43036E-02	-.10685E 00
-.21862E 01	-.78637E 01	.14844E 00	.62140E-01
.63936E 00	-.53015E-01	-.29813E-02	.11011E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.10032E 00	.12056E 00	.70238E 00	-.12967E 01
-.42747E-02	-.81353E-02	.13781E 01	.13043E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.58236E-01	.10793E 00	.20321E 00	.19479E 01

TABLE A3.- Concluded.

Configurations: S30, S31

F MATRIX IS

U	W	Q	THETA	V	P	PHI	R
-.25333E-01	.21210E-01	.42369E 01	-.23890E 02	.73845E-02	.68479E-01	-.19578E-01	.41774E-01
-.91156E-02	-.80676E 00	.11026E 03	.21240E 02	-.12614E-02	.61553E 00	.22317E 00	-.12546E 00
-.44441E-03	-.39055E-01	-.50184E 01	-.62462E 01	-.40060E-03	.28365E 00	.13558E-01	-.10371E 00
.00000E 00	.00000E 00	.99961E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.27823E-01
.34346E-02	-.11613E-02	-.59893E 00	.42676E-01	-.71313E-01	-.34930E 01	.29999E 02	-.98314E 02
-.11910E-02	-.71909E-02	-.24780E 01	.13914E 00	-.51332E-02	-.10001E 02	-.62497E 01	-.46014E 00
.00000E 00	.00000E 00	-.38450E-03	.00000E 00	.00000E 00	.10000E 01	.00000E 00	.13814E-01
-.94437E-02	-.37777E-01	.34751E 00	.86974E 00	.63199E-01	-.14749E 01	-.92154E 00	-.46245E 01

G MATRIX IS

DELTA E	DELTA C	DELTA A	DELTA P
-.84737E 00	.49686E 00	.43282E-02	-.10686E 00
-.21863E 01	-.78640E 01	.14815E 00	.62140E-01
.63935E 00	-.53010E-01	-.29947E-02	.11011E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.10030E 00	.12058E 00	.70236E 00	-.12967E 01
-.42625E-02	-.81310E-02	.13781E 01	.13043E 00
.00000E 00	.00000E 00	.00000E 00	.00000E 00
.58227E-01	.10791E 00	.20321E 00	.19480E 01

TABLE A4.- GEOMETRIC CHARACTERISTICS OF BASELINE HELICOPTER CONFIGURATIONS

Parameter	Rotor type (configuration)		
	Hingeless (S01-S08,S13-S18, S21,S24,S25)	Teetering (S09,S10, S26-S28)	Articulated (S11,S12, S29-S31)
Weight, lb	4,630	8,000	2,200
Main rotor			
x, z, ft	0.08, 5.09	-0.29, 7.02	0.0, 2.79
rpm, rad/sec	44.4	33.9	49.2
Diameter, ft	32.2	48.0	26.3
Chord, ft	0.89	1.75	0.56
Number of blades	4	2	4
Lock number	7.38	6.45	4.92
Solidity	0.070	0.046	0.054
Offset	0.17	0	0.035
Restraint, ft-lb/rad	-12,460	0	0
δ_3, deg	-5.0	0	0
Horizontal tail			
x, z, ft	14.84, 2.08	18.85, 6.87	15.00, 2.70
Area, ft^2	8.67	16.4	7.3
Vertical tail			
x, z, ft	18.10, 4.08	26.90, 45.20	15.40, 2.12
Area, ft^2	10.7	12.0	5.0
Tail rotor			
x, z, ft	19.60, 5.75	28.5, 6.67	15.20, 1.81
rpm, rad/sec	232.4	174	317.2
Diameter, ft	6.23	8.50	4.25
Control throws			
Pitch/roll/yaw, in.	±6/±6/±3.25	±6/±6/±3.25	±6/±6/±3.25
Collective, in.	10	10	10

TABLE A5.- INFLUENCE OF SIDESLIP ON EIGENVALUES OF REDUCED DIRECTIONAL GRADIENT CONFIGURATIONS

Slideslip angle β, deg	Configuration		
	Hingeless (S05)	Teetering (S09)	Articulated (S11)
β = -15°	(10.14)	(9.68)	(9.96)
	(5.02)	(4.74)	(3.91)
	(2.33)	(2.56)	(1.93)
	(0.83)	(1.52)	(0.71;1.93)
	(0.006;0.31)	(0.05;0.23)	(0.10;0.20)
	(0.69;0.42)	(0.95;0.28)	(0.08)
β = 0°	(10.06)	(9.91)	(10.09)
	(5.05)	(4.93)	(0.99;3.09)
	(2.58)	(2.71)	
	(0.76)	(1.41)	(0.67;1.89)
	(-0.007;0.32)	(0.02;0.22)	(0.10;0.18)
	(0.60;0.40)	(0.87;0.25)	(0.08)
β = +15°	(10.08)	(10.02)	(10.19)
	(5.00)	(4.82)	(0.98;3.81)
	(2.77)	(2.74)	(1.87)
	(0.52)	(1.40)	(-0.36;0.31)
	(-0.04;0.36)	(-0.05;0.21)	(0.16;0.20)
	(0.76;0.43)	(0.92;0.28)	

TABLE A6.- RATE DAMPING PLUS INPUT DECOUPLING SCAS GAINS FOR HINGELESS-ROTOR CONFIGURATIONS

Units	Gains	Value
in./in.	Δ_{ES}/δ_{ES}	0.8[a]
in./in.	Δ_{ES}/δ_{CS}	0 for $V_o = 0$
		−0.25 for V_o = 60 knots
		−0.33 for V_o = 80 knots
in./in.	Δ_{AS}/δ_{AS}	0.78[a]
in./in.	Δ_{AS}/δ_{CS}	0.02[a]
in./in.	Δ_{RP}/δ_{CS}	0 for $V_o = 0$
		−0.289 for V_o = 40 knots
		−0.189 for V_o = 60 knots
		−0.167 for V_o = 80 knots
in./in.	Δ_{AS}/δ_{ES}	0.087[a]
in./in.	Δ_{CS}/δ_{CS}	1.0
in./in.	Δ_{RP}/δ_{RP}	1.0
in./rad/sec	$\Delta ES/q$	−1.13
in./rad/sec	$\Delta ES/p$	−2.50
in./rad/sec	$\Delta AS/q$	+2.50
in./rad/sec	$\Delta AS/p$	−0.148
in./rad/sec	$\Delta RP/p$	0.08[a]
in./rad/sec	$\Delta RP/r$	−1.418

[a]Different from reference 6.

TABLE A7.- SUMMARY OF Δ_{ES}/u GAINS FOR HINGELESS-ROTOR STATIC-GRADIENT CONFIGURATIONS

Configuration	Δ_{ES}/u, in./ft/sec
S01, S03, S05, S06 (S13, S15, S17, S18)	0.0135 (all velocities)
S02, S04, S07, S08 (S14, S16)	0 $0 < V_o < 40$ knots
	-0.0019 $V_o = 50$ knots[a]
	-0.0013 $V_o = 60$ knots
	0 $80 < V_o < 100$ knots

[a]Straight-line segments between given values.

TABLE A8.- SUMMARY OF Δ_{AS}/v and Δ_{RP}/v GAINS FOR HINGELESS-ROTOR STATIC-GRADIENT CONFIGURATIONS

Configuration	Δ_{AS}/v, in./ft/sec	Δ_{RP}/v, in./ft/sec
S01, S02	0	0
S05, S07	0	-0.20
S03, S04	+0.0175	0
S06, S08	+0.0160	-0.20

TABLE A9.- CHANGE IN GAINS TO IMPLEMENT TURN-FOLLOWING (TDA) AUGMENTATION SYSTEM

Gains	Rotor type (configuration)			
	Hingeless (S08 → S21)	Teetering (S10 → S26)	Articulated (S12 → S29)	
Δ_{RP}/δ_{AS}	-0.056	0	0	
Δ_{RP}/r	-0.662	-0.81	-0.87	
Δ_{RP}/v	+0.041	+0.0503	0	$0 < V_o < 30$ knots
			+0.0043	$V_o = 40$ knots
			+0.027	$V_o = 60$ knots
			+0.031	$V_o = 80$ knots

TABLE A10.- ADDITIONAL GAINS FOR ATTITUDE COMMAND SCAS CONFIGURATIONS

Gains	Rotor type (configuration)		
	Hingeless (S24)	Teetering (S27)	Articulated (S30)
Δ_{ES}/θ, in./rad	-5.94	-36.69	-10.59
Δ_{AS}/ϕ, in./rad	-2.72	-15.16	-6.08

APPENDIX B

MOTION SYSTEM DRIVE LOGIC FOR THE FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT

There has been a great deal of physiological and psychological research in the areas of sensing, perception, and utilization of motion cues by the human pilot. However, several aspects of these phenomena are still not well defined. It is not known what motion cues are essential to produce simulator pilot performance that adequately duplicates flight performance. This duplication is further hampered by the performance limitations of the simulation hardware. Therefore, the drive logic that most effectively matches the simulator's capabilities to a particular aircraft and task is arrived at by a mixture of quantitative and qualitative means.

The intent of the current drive logic for the Flight Simulator for Advance Aircraft (FSAA) is to provide the pilot with motion cues that are as realistic as possible while still safely keeping the simulator within its physical performance boundaries (i.e., position, velocity, and acceleration limits). This logic is embodied in what is known as the Motion Washout Program in the digital simulation computer. A schematic representation of the closed-loop system formed by the simulation computer, motion system, and pilot is presented in figure B1.

To gain an understanding of how the calculated kinematics of the aircraft model are transmitted to the pilot in this system, one might construct transfer functions to describe the Motion System and Motion Washout Program. Some investigations have been performed to identify the dynamic characteristics of the Motion System such that a transfer function description of that system could be established. For most simulation tasks, however, the kinematics of interest have a frequency content that is well below the characteristic frequencies of the motion system. This system would, therefore, appear as a unity transfer function for these tasks.

The Motion Washout Program (see fig. B2) utilizes digital high-pass and low-pass filter techniques along with axes transformations, axes cross-coupling, and nonlinear elements, such as dynamic scaling and limiters. Hence, an exact linear transfer function description of that program does not exist. However, an understanding of the Washout Program and its effect on the aircraft kinematics can be gained by considering the transfer functions that are valid for certain sets of limited operating conditions.

Consider the following limited operating conditions and assumptions which allow a transfer function description of the Washout Program.

1. The filtered kinematics are sufficiently within the performance boundaries of the simulator that nonlinearities associated with limiting can be neglected.

2. The angular displacements of the simulator are small enough that the following approximations are reasonable:

$\sin \theta_s \doteq \theta_s \qquad \cos \theta_s \doteq 1$

$\sin \phi_s \doteq \phi_s \qquad \cos \phi_s \doteq 1$

$\sin \psi_s \doteq \psi_s \qquad \cos \psi_s \doteq 1$

3. Each axis of the Washout Program can be considered separately. That is, for transfer functions related to any one input (e.g., A_{xp}), the remaining five inputs are assumed to be zero. This allows cross-coupling due to axes transformations to be neglected.

4. Since we can assume that the motion system itself is a unity transfer function, the position feedback loop to the motion washout program can be neglected.

The resulting transfer functions expressed in simulator drive axes (subscript s) are given by equations (B1)-(B9) below.

$$\frac{A_{xs}}{A_{xp}} = \frac{K_x K_{hx}\{(s+\omega_{1q})(s+\omega_{2q})(s^2+2\zeta_{3q}\omega_{3q}s+\omega_{3q}^2) - K_n\omega_{1q}\omega_{2q}\omega_{3q}^2\} \cdot s^4}{(s+\omega_{1q})(s+\omega_{2q})(s^2+2\zeta_{3q}\omega_{3q}s+\omega_{3q}^2)(s^2+2\zeta_{1x}\omega_{1x}s+\omega_{1x}^2)(s^2+2\zeta_{2x}\omega_{2x}s+\omega_{2x}^2)} \tag{B1}$$

$$\frac{A_{ys}}{A_{yp}} = \frac{K_y K_{hy}\{(s+\omega_{1p})(s+\omega_{2p})(s^2+2\zeta_{3p}\omega_{3p}s+\omega_{3p}^2) - K_n\omega_{1p}\omega_{2p}\omega_{3p}^2\} \cdot s^4}{(s+\omega_{1p})(s+\omega_{2p})(s^2+2\zeta_{3p}\omega_{3p}s+\omega_{3p}^2)(s^2+2\zeta_{1y}\omega_{1y}s+\omega_{1y}^2)(s^2+2\zeta_{2y}\omega_{2y}s+\omega_{2y}^2)} \tag{B2}$$

$$\frac{A_{zs}}{A_{zp}} = \frac{K_z K_{hz} \cdot s^4}{(s^2+2\zeta_{1z}\omega_{1z}s+\omega_{1z}^2)(s^2+2\zeta_{2z}\omega_{2z}s+\omega_{2z}^2)} \tag{B3}$$

$$\frac{\theta_s}{A_{xp}} = \frac{K_x K_{x\ell} K_n \omega_{1q}\omega_{2q}\omega_{3q}^2}{g(s+\omega_{1q})(s+\omega_{2q})(s^2+2\zeta_{3q}\omega_{3q}s+\omega_{3q}^2)} \tag{B4}$$

$$\frac{\phi_s}{A_{yp}} = \frac{-K_y K_{y\ell} K_n \omega_{1p}\omega_{2p}\omega_{3p}^2}{g(s+\omega_{1p})(s+\omega_{2p})(s^2+2\zeta_{3p}\omega_{3p}s+\omega_{3p}^2)} \tag{B5}$$

$$\frac{\phi_s}{\dot{p}_b} = \frac{K_p s^2}{(s^2+2\zeta_p\omega_p s+\omega_p^2)(s^2+2\zeta_{\phi e}\omega_{\phi e}s+\omega_{\phi e}^2)} \tag{B6}$$

$$\frac{y_s}{\dot{p}_b} = \frac{g \cdot K_{ny} K_p s^2}{(s^2+2\zeta_{ye}\omega_{ye}s+\omega_{ye}^2)(s^2+2\zeta_p\omega_p s+\omega_p^2)(s^2+2\zeta_{\phi e}\omega_{\phi e}s+\omega_{\phi e}^2)} \tag{B7}$$

$$\frac{\theta_s}{\dot{q}_b} = \frac{K_q s^2}{(s^2+2\zeta_q\omega_q s+\omega_q^2)(s^2+2\zeta_{\theta e}\omega_{\theta e}s+\omega_{\theta e}^2)} \tag{B8}$$

$$\frac{\psi_s}{\dot{r}_b} = \frac{K_r s^2}{(s+2\zeta_r\omega_r s+\omega_r^2)(s^2+2\zeta_{\psi e}\omega_{\psi e}s+\omega_{\psi e}^2)} \tag{B9}$$

Before transforming these functions to the pilot axes, further simplifying assumptions can be made based on conditions that were prevalent during the subject simulation.

The K_n in equations (B1) through (B9) is a dynamic scale factor; that is,

$$K_n \equiv \frac{g}{(A_{xp}^2+A_{yp}^2+A_{zp}^2)^{1/2}}$$

If, in addition to condition (4) stated earlier, we assume that the A_{xp} and A_{yp} inputs we are considering are much less than 1 g and that A_{zp} stays near a trim value of -1 g, we can approximate K_n by unity.

The primary reason for having a second set of high-pass filters in the washout circuit is to cause the position of the simulator to continually wash back to zero (center of travel). The characteristic frequencies of these second filters are set to be below the pilot's threshold of perception; that is, their effect on specific forces (A_{xp}, A_{yp}, A_{zp}) and angular accelerations ($\dot{p}_b$, $\dot{q}_b$, $\dot{r}_b$) is negligible compared to the first filters. We may, therefore, assume that the frequencies of the second set of filters are zero.

The data in table B1 show that we can let

$$\omega_1 = \omega_{1p} = \omega_{1q} = \omega_{1r}$$

$$\zeta_1 = \zeta_{1p} = \zeta_{1q} = \zeta_{1r}$$

$$\omega_2 = \omega_{2p} = \omega_{2q} = \omega_{2r}$$

$$\zeta_2 = \zeta_{2p} = \zeta_{2q} = \zeta_{2r}$$

$$\omega_3 = \omega_{3p} = \omega_{3q} = \omega_{3r}$$

$$\zeta_3 = \zeta_{3p} = \zeta_{3q} = \zeta_{3r}$$

and that we can let several gains be unity.

TABLE B1.- MOTION PARAMETER VALUES FOR THIS EXPERIMENT

$K_x = 0.75$	$K_p = 0.50$	$K_{nx} = 0$	$K_{hx} = 1.0$	$K_{ax} = 0.2$	$K_{ap} = 0.5$
$K_y = 0.75$	$K_q = 0.50$	$K_{ny} = 1.0$	$K_{hy} = 1.0$	$K_{ay} = 0.1$	$K_{aq} = 0.5$
$K_z = 0.50$	$K_r = 0.50$	$K_{nz} = 1.0$[a]	$K_{hz} = 1.0$	$K_{az} = 0.1$	$K_{ar} = 0.5$

$K_{x\ell} = 1.0$ Damping ratio, $\zeta_n = 0.707$, n = 1x,2x,1y,2y, ... for all filters.

$K_{y\ell} = 1.0$

First high-pass filters

$\omega_{1x} = 0.8$	$\omega_p = 0.7$
$\omega_{1y} = 0.7$	$\omega_q = 0.7$
$\omega_{1z} = 2.0$	$\omega_r = 0.7$

Second high-pass filters

$\omega_{2x} = 0.20$	$\omega_{\phi e} = 0.20$
$\omega_{2y} = 0.05$	$\omega_{\theta e} = 0.20$
$\omega_{2z} = 0.20$	$\omega_{\psi e} = 0.20$

Low-pass filters

$\omega_{1p} = 3.0$	$\omega_{2p} = 2.0$	$\omega_{3p} = 1.2$
$\omega_{1q} = 3.0$	$\omega_{2q} = 2.0$	$\omega_{3q} = 1.2$
$\omega_{1r} = 3.0$	$\omega_{2r} = 2.0$	$\omega_{3r} = 1.2$

Note: The Washout Program was coded so that the cue coordination circuit was active for y/ϕ only.

[a]Not used in circuit for this study.

Applying these assumptions and conditions, equations (B1) through (B9) reduce to the following:

$$\frac{A_{xs}}{A_{xp}} = \frac{K_x s^2}{(s^2+2\zeta_{1x}\omega_{1x}s+\omega_{1x}^2)} - \frac{K_x\omega_1\omega_2\omega_3^2 s^2}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)(s^2+2\zeta_{1x}\omega_{1x}s+\omega_{1x}^2)} \quad \text{(B10)}$$

$$\frac{A_{ys}}{A_{yp}} = \frac{K_y s^2}{(s^2+2\zeta_{1y}\omega_{1y}s+\omega_{1y}^2)} - \frac{K_y\omega_1\omega_2\omega_3^2 s^2}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)(s^2+2\zeta_{1y}\omega_{1y}s+\omega_{1y}^2)} \quad \text{(B11)}$$

$$\frac{A_{zs}}{A_{zp}} = \frac{K_z s^2}{(s^2+2\zeta_{1z}\omega_{1z}s+\omega_{1z}^2)} \quad \text{(B12)}$$

$$\frac{\theta_s}{A_{xp}} = \frac{K_x\omega_1\omega_2\omega_3^2}{g(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)} \quad \text{(B13)}$$

$$\frac{\phi_s}{A_{yp}} = \frac{-K_y\omega_1\omega_2\omega_3^2}{g(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)} \quad \text{(B14)}$$

$$\frac{\phi_s}{\dot{p}_b} = \frac{K_p}{(s^2+2\zeta_p\omega_p s+\omega_p^2)} \quad \text{(B15)}$$

$$\frac{y_s}{\dot{p}_b} = \frac{g \cdot K_p}{s^2(s^2+2\zeta_p\omega_p s+\omega_p^2)} \quad \text{(B16)}$$

$$\frac{\theta_s}{\dot{q}_b} = \frac{K_q}{(s^2+2\zeta_q\omega_q s+\omega_q^2)} \quad \text{(B17)}$$

$$\frac{\psi_s}{\dot{r}_b} = \frac{K_r}{(s^2+2\zeta_r\omega_r s+\omega_r^2)} \quad \text{(B18)}$$

The specific forces and angular accelerations in simulator axes (subscript c) can be transformed to pilot axes as follows:

$$
\begin{aligned}
A_{xc} &= A_{xs} + g\theta s \quad , \quad \dot{p}_c = \ddot{\phi}_s \\
A_{yc} &= A_{ys} - g\phi s \quad , \quad \dot{q}_c = \ddot{\theta}_s \\
A_{zc} &= A_{zs} \quad , \quad \dot{r}_c = \ddot{\psi}_s
\end{aligned}
\tag{B19}
$$

And consequently,

$$
\begin{aligned}
\frac{A_{xc}}{A_{xp}} &= \frac{A_{xs}}{A_{xp}} + g\,\frac{\theta_s}{A_{xp}} \quad , \quad \frac{\dot{p}_c}{\dot{p}_b} = s^2\,\frac{\phi_s}{\dot{p}_b} \\
\frac{A_{yc}}{A_{yp}} &= \frac{A_{ys}}{A_{yp}} - g\,\frac{\phi_s}{A_{yp}} \quad , \quad \frac{\dot{q}_c}{\dot{q}_b} = s^2\,\frac{\theta_s}{\dot{q}_b} \\
\frac{A_{zc}}{A_{zp}} &= \frac{A_{zs}}{A_{zp}} \quad , \quad \frac{\dot{r}_c}{\dot{r}_b} = s^2\,\frac{\psi_s}{\dot{r}_b} \\
\frac{\dot{q}_c}{A_{xp}} &= s^2\,\frac{\theta_s}{A_{xp}} \quad , \quad \frac{A_{xc}}{\dot{q}_b} = \frac{A_{xs}}{\dot{q}_b} + g\,\frac{\theta_s}{\dot{q}_b} \\
\frac{\dot{p}_c}{A_{yp}} &= s^2\,\frac{\phi_s}{A_{yp}} \quad , \quad \frac{A_{yc}}{\dot{p}_b} = s^2\left(\frac{y_s}{\dot{p}_b}\right) - g\,\frac{\phi_s}{\dot{p}_b}
\end{aligned}
\tag{B20}
$$

Using equations (B10) through (B18), the expressions in (B20), and the fact that $A_{xs}/\dot{q}_b = 0$ for this simulation, the following transfer functions are obtained.

$$
\frac{A_{xc}}{A_{xp}} = K_x\left\{\frac{s^2}{(s^2+2\zeta_{1x}\omega_{1x}s+\omega_{1x}^2)} + \frac{2\zeta_{1x}\omega_{1x}\omega_1\omega_2\omega_3^2\left(s+\frac{\omega_{1x}}{2\zeta_{1x}}\right)}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)(s^2+2\zeta_{1x}\omega_{1x}s+\omega_{1x}^2)}\right\}
\tag{B21}
$$

$$
\frac{A_{yc}}{A_{yp}} = K_y\left\{\frac{s^2}{(s^2+2\zeta_{1y}\omega_{1y}s+\omega_{1y}^2)} + \frac{2\zeta_{1y}\omega_{1y}\omega_1\omega_2\omega_3^2\left(s+\frac{\omega_{1y}}{2\zeta_{1y}}\right)}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)(s^2+2\zeta_{1y}\omega_{1y}s+\omega_{1y}^2)}\right\}
\tag{B22}
$$

$$\frac{A_{zc}}{A_{zp}} = \frac{K_z s^2}{(s^2+2\zeta_{1z}\omega_{1z}s+\omega_{1z}^2)} \tag{B23}$$

$$\frac{\dot{p}_c}{\dot{p}_b} = \frac{K_p s^2}{(s^2+2\zeta_p\omega_p s+\omega_p^2)} \tag{B24}$$

$$\frac{\dot{q}_c}{\dot{q}_b} = \frac{K_q s^2}{(s^2+2\zeta_q\omega_q s+\omega_q^2)} \tag{B25}$$

$$\frac{\dot{r}_c}{\dot{r}_b} = \frac{K_r s^2}{(s^2+2\zeta_r\omega_r s+\omega_r^2)} \tag{B26}$$

$$\frac{\dot{q}_c}{A_{xp}} = \frac{K_x\omega_1\omega_2\omega_3^2}{g} \cdot \frac{s^2}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)} \tag{B27}$$

$$\frac{\dot{p}_c}{A_{yp}} = \frac{-K_y\omega_1\omega_2\omega_3^2}{g} \cdot \frac{s^2}{(s+\omega_1)(s+\omega_2)(s^2+2\zeta_3\omega_3 s+\omega_3^2)} \tag{B28}$$

$$\frac{A_{xc}}{\dot{q}_b} = \frac{g \cdot K_q}{(s^2+2\zeta_q\omega_q s+\omega_q^2)} \tag{B29}$$

$$\frac{A_{yc}}{\dot{p}_b} = \frac{g\,K_p}{(s^2+2\zeta_p\omega_p s+\omega_p^2)} - \frac{g\,K_p}{(s^2+2\zeta_p\omega_p s+\omega_p^2)} \equiv 0 \tag{B30}$$

The frequency response data (magnitude and phase angle versus frequency) for these transfer functions is presented in figures B3 through B14.

Since

$$K_p = K_q = K_r$$

$$\omega_p = \omega_q = \omega_r$$

$$\zeta_p = \zeta_q = \zeta_r \quad \text{(see table B1)}$$

the transfer functions of equations (B24) through (B26) are identical and are therefore represented by only one set of frequency response data (figs. B9, B10).

Also,

$$K_x = K_y$$

$$\omega_{1p} = \omega_{1q} = \omega_{1r}$$

$$\omega_{2p} = \omega_{2q} = \omega_{3r}$$

$$\zeta_{1p} = \zeta_{1q} = \zeta_{1r}$$

$$\zeta_{2p} = \zeta_{2q} = \zeta_{2r} \quad \text{(see table B1)}$$

Therefore, the transfer functions of equations (B27) and (B28) are identical (except for sign) and are represented by only one set of data in figures B11 and B12.

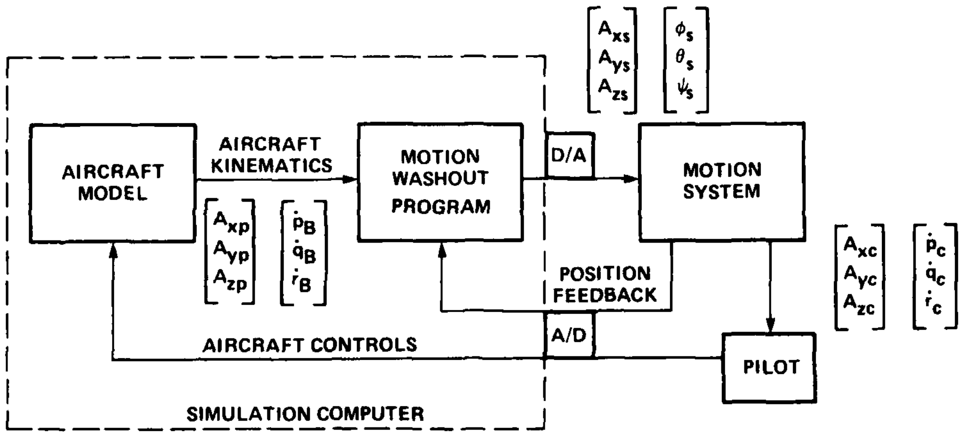

Figure B1.- Closed-loop simulation operation.

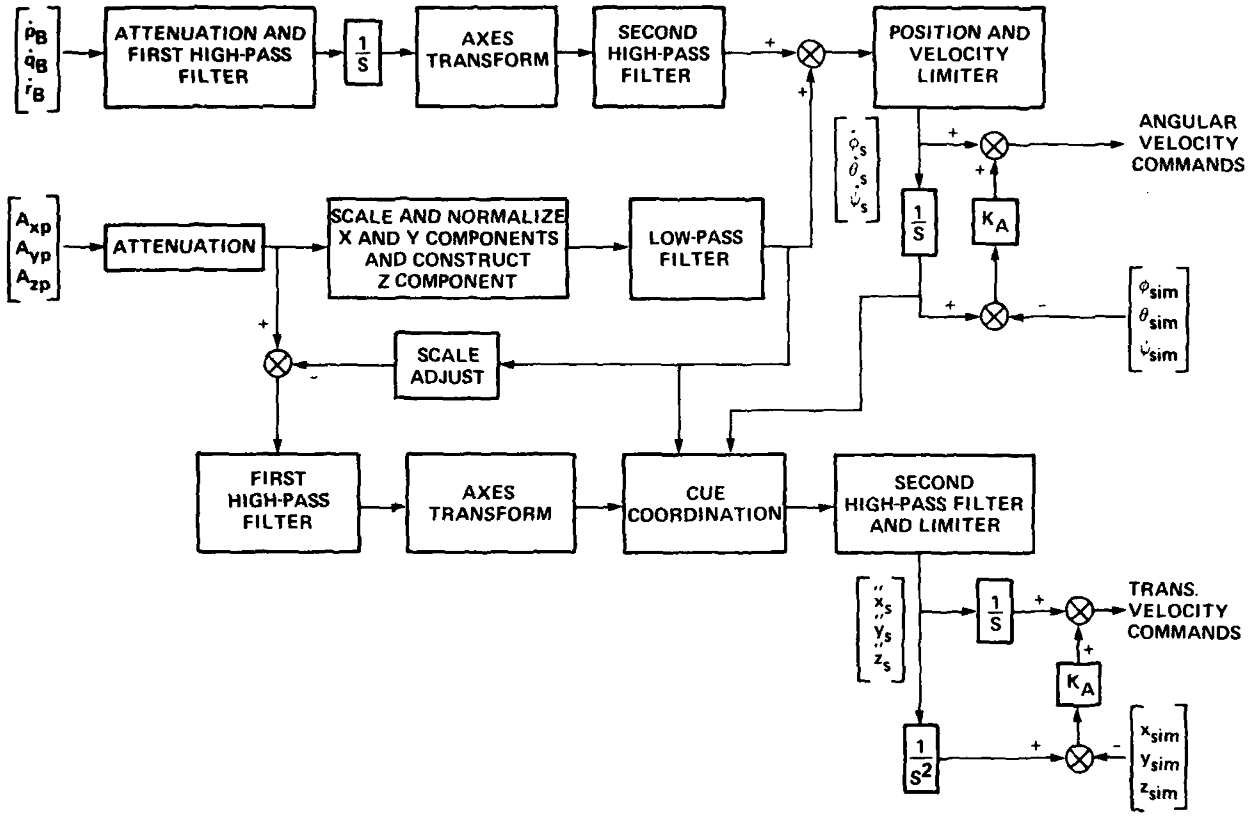

Figure B2.- Functional flow of the Motion Washout Program for the FSAA.

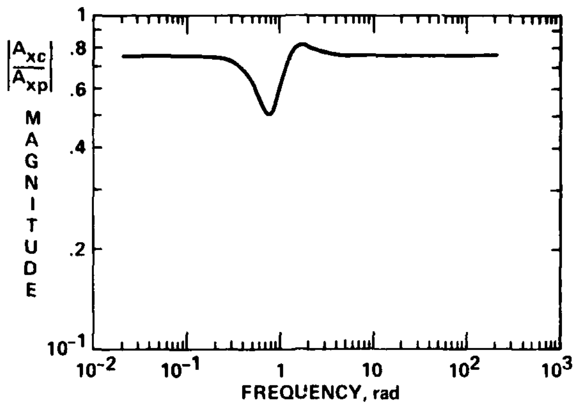

Figure B3.- Transfer function frequency response magnitude for A_{xc}/A_{xp}.

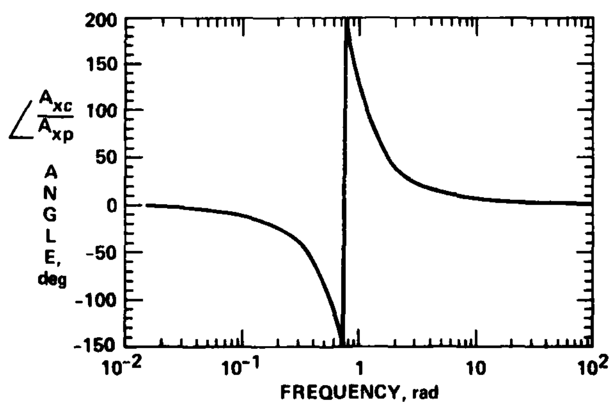

Figure B4.- Transfer function frequency response phase angle for A_{xc}/A_{xp}.

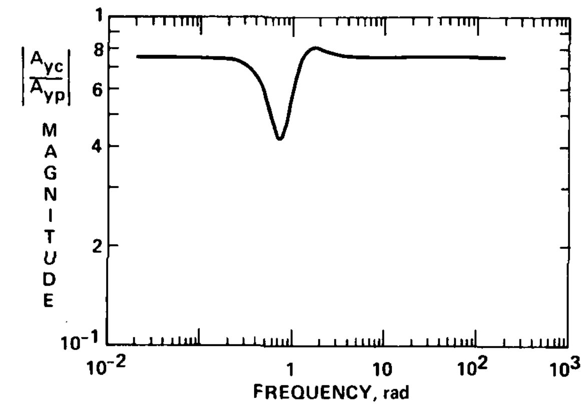

Figure B5.- Transfer function frequency response magnitude for A_{yc}/A_{yp}.

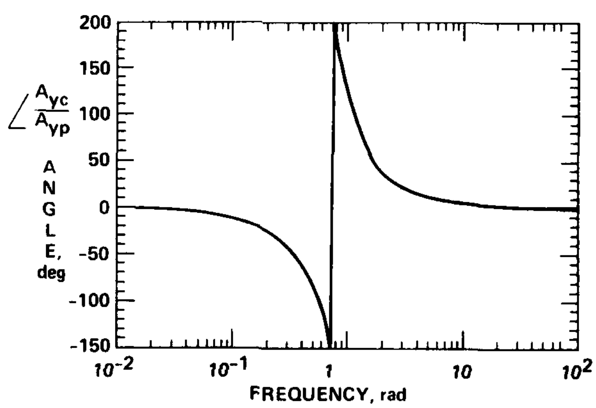

Figure B6.- Transfer function frequency response phase angle for A_{yc}/A_{yp}.

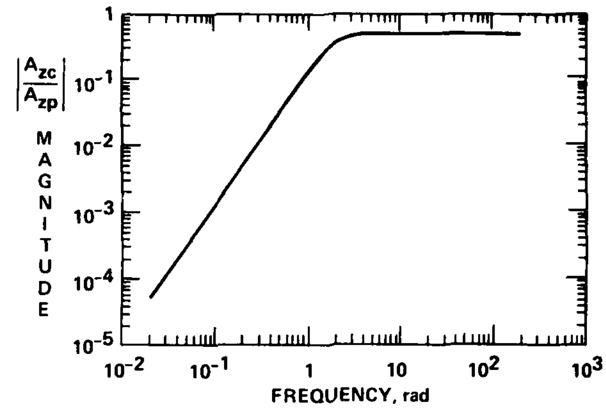

Figure B7.- Transfer function frequency response magnitude for A_{zc}/A_{zp}.

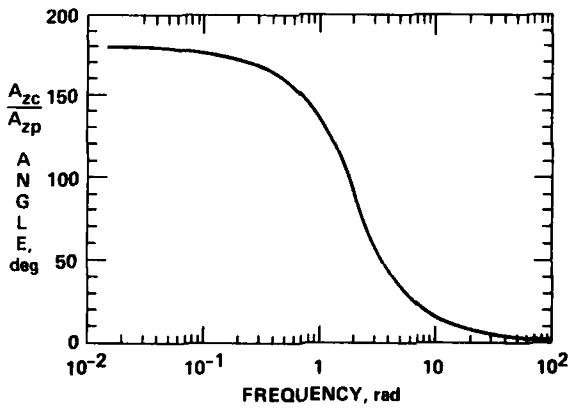

Figure B8.- Transfer function frequency response phase angle for A_{zc}/A_{zp}.

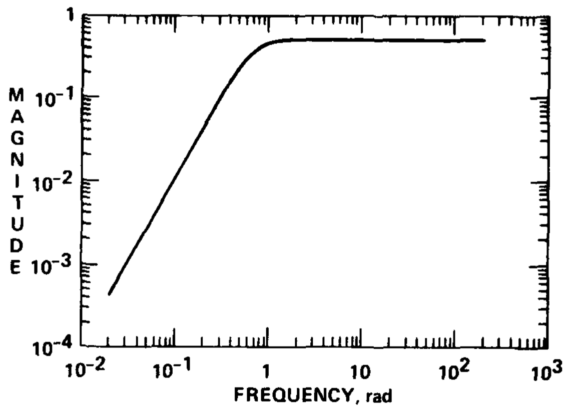

Figure B9.- Transfer function frequency response magnitude for $\dot{p}_c/\dot{p}_b$, $\dot{q}_c/\dot{q}_b$, and $\dot{r}_c/\dot{r}_b$.

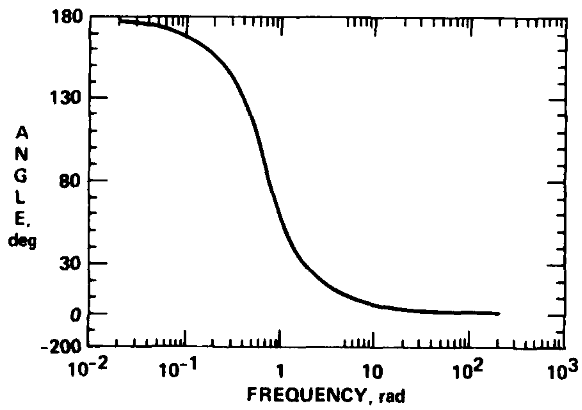

Figure B10.- Transfer function frequency response phase angle for $\dot{p}_c/\dot{p}_b$, $\dot{q}_c/\dot{q}_b$, and $\dot{r}_c/\dot{r}_b$.

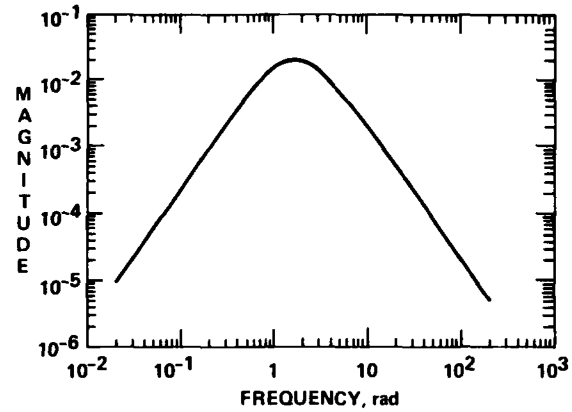

Figure B11.- Transfer function frequency response magnitude for $\dot{q}_c/A_{xp}$ and $\dot{p}_c/A_{yp}$.

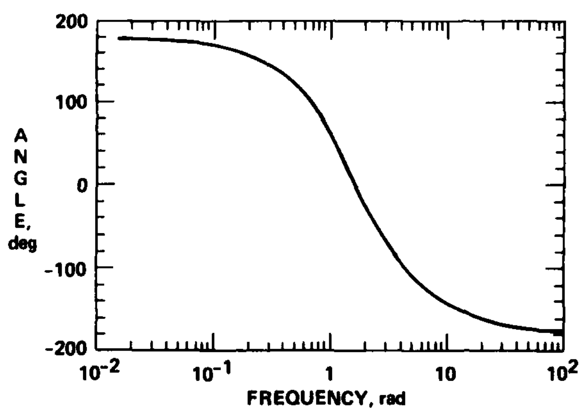

Figure B12.- Transfer function frequency response phase angle for $\dot{q}_c/A_{xp}$ and $\dot{p}_c/A_{yp}$.

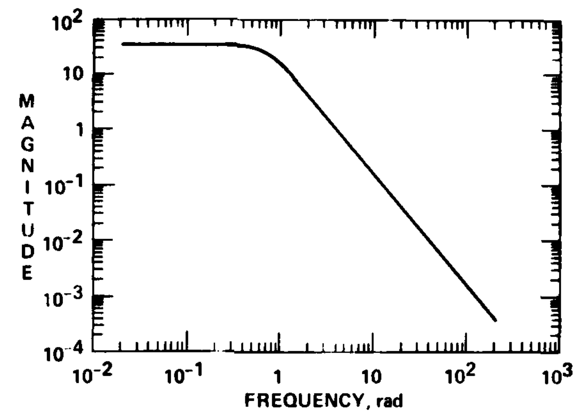

Figure B13.- Transfer function frequency response magnitude for $A_{xc}/\dot{q}_b$.

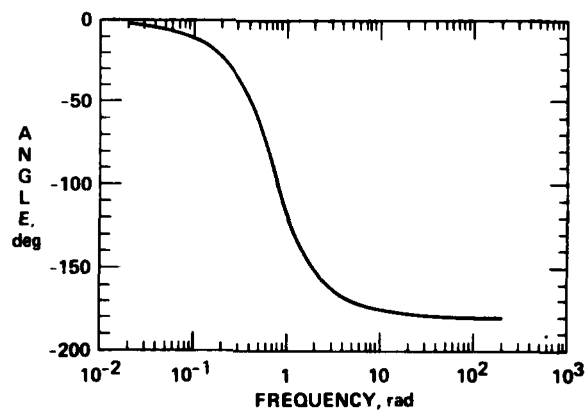

Figure B14.- Transfer function frequency response phase angle for $A_{xc}/\dot{q}_b$.

APPENDIX C

CONFIGURATION ID: S01	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:** G
LATERAL POSITION GRADIENT: 0.57 in./15°	4	**FORCE FEEL:** ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 1-3	**SCAS:** RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed control, decoupling. Very little change in speed with power changes for climb, very little attitude change required.

OBJECTIONABLE FEATURES: Some problem with inadvertent roll excursions.

REASON FOR RATING: Deficiencies warrant improvement. Lack of an attitude-stabilization feature is deficiency. Airplane relatively easy to fly through this task.

SPECIFICS:

TRIM: Good in all three axes. Using mag brake system. No requirements for large retrims.

PITCH RESPONSE: Predictable, no overshoot or bobble, no coupling into roll axis. Positive longitudinal static stability.

ROLL RESPONSE: Looks good, no coupling to pitch.

SPEED CONTROL: Did well, stayed within 5 knots.

TURN COORDINATION: Good. Some tendency to fly airplane with right sideslip.

THRUST CONTROL: Good, coupling almost entirely removed.

TASK PERFORMANCE: Deceleration satisfactory — some problem with scanning for altitude control during deceleration. VOR acquisition and tracking OK, heading control is good even though some bank angle wandering. Descent good — takes some time to get onto 1000 fpm, but, once on, airplane trims out nicely. Missed approach hardest maneuver. Some tendency to let bank angle get away and thus turn rate. Climb rate and airspeed control pretty good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S01	**PILOT RATING (IN TURBULENCE)** 5½	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:** C	
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 1-3	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Turbulence-aggravated attitude disturbances, not just roll but pitch and yaw too.

REASON FOR RATING: Reflects increased workload, decreased precision.

SPECIFICS:

TRIM: Hindered by motion caused by turbulence, had to continually retrim.

PITCH RESPONSE: Turbulence disturbed precision.

ROLL RESPONSE: Turbulence disturbed precision.

SPEED CONTROL: Degraded, particularly in missed approach climb.

TURN COORDINATION: Not a problem.

THRUST CONTROL: Not a problem.

TASK PERFORMANCE: VOR acquisition degraded because of attitude disturbances. Descent somewhat unsteady. Big thing in missed approach was unsteady turn rate.

EFFECTS OF TURBULENCE: Looked like primarily roll, then pitch, then directional. No real coupling concerns though.

CONFIGURATION ID: S01	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:** H	
LATERAL POSITION GRADIENT: 0.57 in./15°	4½	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 8-10	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Static stability, turn coordination.

OBJECTIONABLE FEATURES: Constant corrections to hold bank or attitude.

REASON FOR RATING: Deficiencies were moderately objectionable.

SPECIFICS:

TRIM: No problems.

PITCH RESPONSE: Predictable.

ROLL RESPONSE: Predictable, but constant corrections required.

SPEED CONTROL:

TURN COORDINATION: Could keep ball within reasonable degree of being centered.

THRUST CONTROL: Slight amount of collective to pitch and roll was not enough to interfere with task performance.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S01	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5		PILOT:	H
LATERAL POSITION GRADIENT:	0.57 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS:	8-10	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE: More difficult with turbulence.

SPEED CONTROL: A little worse, but within 10 knot tolerance.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Primarily bank angle control, some degradation of speed control.

CONFIGURATION ID: S01	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	4	**PILOT:** G	
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 137-139	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Task performed fairly well. Good airspeed control.

OBJECTIONABLE FEATURES: Lack of attitude loop makes workload fairly high. Seemed to need pedal in turn, made turn rate a little unsteady.

REASON FOR RATING: Needs improvement, mildly unpleasant. Feel that for single-pilot IFR an attitude loop is required to help with auxiliary tasks of radio or charts.

SPECIFICS:

TRIM: Good short term. Used force-release.

PITCH RESPONSE: Good dynamics, sensitivity, forces. No coupling.

ROLL RESPONSE: Good dynamics, sensitivity, forces. No coupling.

SPEED CONTROL: Pretty good. Nose came up a couple of times when I lost my scan, pitch attitude system would help. Positive longitudinal stability noted during free run.

TURN COORDINATION: Seemed not to be big problem. Did feel some side force, ball out in left turns. No proverse or adverse yaw noted rolling in or out. No problem holding heading.

THRUST CONTROL: Good; coupling not a big problem.

TASK PERFORMANCE: Some climbing in deceleration. VOR capture good, tracking good. Descent, transitions OK, may have lost 5 knots, never got to 10 knots error. Missed approach good: applied power first, then roll into turn and check pitch attitude.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S01	**PILOT RATING (IN TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	5	**PILOT:** G	
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 137-139	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Considerable compensation required.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Not quite as good. More compensation required to pay attention to pitch and roll attitudes.

TURN COORDINATION: Seemed same — OK.

THRUST CONTROL: Seemed same — OK.

TASK PERFORMANCE: About the same. VOR acquisition degraded, but maybe I didn't try as hard. VOR tracking and descent OK, aircraft likes the 1000 fpm descent, certainly stays right on VOR radial. Missed approach not bothered much, some increase in attitude disturbances but only required a little more compensation.

EFFECTS OF TURBULENCE: Workload higher, performance degraded, but not by a great deal. Turbulence is relatively mild compared to what you might get near any kind of weather situation. Inputs mostly noticeable in pitch.

CONFIGURATION ID:	S01	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°	4½		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	167-169	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Trying to get established in smooth, comfortable turn for go-around.

REASON FOR RATING: *Concentration required for turn and to maintain airspeed, rate of climb.*

SPECIFICS:

TRIM: Fine. Used both rate and trim-release systems.

PITCH RESPONSE: Fine. Predictable, not supersensitive. Coupling not noticeable.

ROLL RESPONSE: Not glaringly bad, but can't predict as well as pitch. Have to fly through turn all the time, can't set it up and let it be, have to keep correcting to maintain rate of turn.

SPEED CONTROL: Adequate. Takes long time to wander and also long time to come back. If don't want to make radical nose change, just accept deviation and make slow change.

TURN COORDINATION: Not using much rudder — maybe part of problem. Very difficult to set up coordinated turn, ball in center.

THRUST CONTROL: Coupling no big factor. Satisfactory.

TASK PERFORMANCE: Deceleration and VOR acquisition OK. VOR tracking acceptable, should be doing better — I'll get off in course of scan or not getting correction back in time. Descent OK, some deviations in speed and sink rate until it's settled out. Missed approach most difficult part, ran into turn and attitude difficulties there. Saw maybe 8 knots deviation in airspeed during missed approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S01	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	5	**PILOT:**	K
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 167-169	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Lack of coupling with power changes.

OBJECTIONABLE FEATURES: Overbank in missed approach, a bobble in trying to get a turn set up. Translates into attitude changes and general deterioration in performance. Uncomfortable in turns.

REASON FOR RATING: Moderately objectional deficiencies, considerable pilot compensation.

SPECIFICS:

TRIM: Fine. Not real preoccupied with trimming since mostly tiny corrections required. Used both systems.

PITCH RESPONSE: Fine, predictable, does require attention particularly in turn. If scan isn't fast enough, you wander off, results in speed or sink change.

ROLL RESPONSE: Not predictable, isn't very precise for me.

SPEED CONTROL: Very flat power curve, have to be patient with speed changes, not a fast transition back to a speed

TURN COORDINATION:

THRUST CONTROL: OK, same comments.

TASK PERFORMANCE: Deceleration and VOR acquisition OK, same comments. Are intercepting (radial) in close, don't have much time for setting up tracking before station passage, needle will move off when you're a little off even if you have a perfectly fine heading. Descent OK. Missed approach sloppiest part of process. Got 10 knots off, somewhat wobbly in the turn. Pitch attitude control deteriorated because of preoccupation required for turn.

EFFECTS OF TURBULENCE: Have to sort out if upset is due to you or turbulence, sort of interpolate.

CONFIGURATION ID: S01	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	4	PILOT:	H
LATERAL POSITION GRADIENT: 0.57 in./15°		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	RUNS: 186-188	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Relatively minor coupling to various axes. Although a little collective to roll and pitch was noted VFR, didn't create problems IFR.

OBJECTIONABLE FEATURES: Need for constant small corrections, required continuous monitoring.

REASON FOR RATING: Minor but annoying deficiency.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S01	**PILOT RATING (IN TURBULENCE)** 5	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:** H	
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 186-188	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Responses fairly predictable. Seemed stable in all axes.

OBJECTIONABLE FEATURES: Constant small corrections required.

REASON FOR RATING: Could handle quite a bit worse configuration but still required considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Workload up quite a bit.

CONFIGURATION ID: S01	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	4½	**PILOT:**	M
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 296-298	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Tendency for slow departure in pitch unless I look at pitch continuously.

REASON FOR RATING: Desired performance attainable, but workload between moderate and considerable.

SPECIFICS:

TRIM: Good in longitudinal, lateral. Beeper used exclusively.

PITCH RESPONSE: Seems to be a threshold on initial response. Doesn't couple to other axes, response good, predictability good.

ROLL RESPONSE: Roll couples slightly to pitch, is quite marked.

SPEED CONTROL: Good except in go-around due to lack of accurate pitch control there. Speed to pitch attitude was quite good.

TURN COORDINATION: No problems.

THRUST CONTROL: No problems.

TASK PERFORMANCE: Deceleration no problem, tracking OK, descent no problem at all. Missed approach quite difficult, particularly speed control and combination of speed and pitch attitude control.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S01	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		7	**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	296-298	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Roll control precise, crisp. No problems with power or yaw control.

OBJECTIONABLE FEATURES: Pitch departure quite rapid, response to control appears sluggish.

REASON FOR RATING: Pitch and airspeed control not good in turbulence.

SPECIFICS:

TRIM: Can trim longitudinal long term. Lateral and directional can trim. Beeper used.

PITCH RESPONSE: Covered above.

ROLL RESPONSE: No problem.

SPEED CONTROL: Fine, good, adequate. Speed stability OK, a bit backsided but nothing much. My problem is in pitch control.

TURN COORDINATION: No problem.

THRUST CONTROL: No sweat.

TASK PERFORMANCE: Deceleration, tracking, descent OK. Missed approach lousy. It's in response to really large flightpath disturbances that this problem becomes apparent. Would not like to fly this aircraft IFR.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S01	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°	4½		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	308-311	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Stability good.

OBJECTIONABLE FEATURES: Problem with smooth coordinated roll.

REASON FOR RATING:

SPECIFICS:

TRIM: Used mag brake and beeper. No rudder trim.

PITCH RESPONSE: Good.

ROLL RESPONSE: Difficulty with roll, although pretty good in this aircraft I thought. Still am overbanking.

SPEED CONTROL: Good.

TURN COORDINATION: Ratchety.

THRUST CONTROL: OK.

TASK PERFORMANCE: Adequate, satisfactory with exception of tendency to overshoot 1600 ft on climbout. Missed approach is hardest, am banked steeper there than I am in earlier part of approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S01	**PILOT RATING (IN TURBULENCE)**	4½	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	308-311	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: All comments the same.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: No change.

CONFIGURATION ID:	S02	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°	7		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	4-7.	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Bank angle wandering resolving into turn rate control. Lack of force change with speed also certainty showed up as poor speed control.

REASON FOR RATING: Poor speed control.

SPECIFICS:

TRIM: OK. Using mag brake.

PITCH RESPONSE: Satisfactory. Neutral static force gradient.

ROLL RESPONSE: Satisfactory, but want attitude stabilization for power inputs.

SPEED CONTROL: Bad. Attribute it to lack of force change, stick-free stability.

TURN COORDINATION: No problem.

THRUST CONTROL: No problem, no coupling problems.

TASK PERFORMANCE: Deceleration not good. VOR acquisition and tracking not affected, good. Problem was longitudinal speed control.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S02	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	7	**PILOT:**	G
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 4-7 .	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Comments lost: tape malfunction.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S02	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:** H	
LATERAL POSITION GRADIENT: 0.57 in./15°	5	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 11-13	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turn coordination.

OBJECTIONABLE FEATURES: Lack of static longitudinal stability, bank attitude excursions. Lack of static stability didn't really hit me as too bad — slightly objectionable.

REASON FOR RATING: Considerable pilot compensation required.

SPECIFICS:

TRIM: No problem except lack of speed stability with longitudinal trim.

PITCH RESPONSE: No real problem.

ROLL RESPONSE: No real problem.

SPEED CONTROL: No real problem.

TURN COORDINATION: No real problem.

THRUST CONTROL: No real problem.

TASK PERFORMANCE: No real problem.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S02	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		5½	**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	11-13	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Some more problems with airspeed control and bank attitude control.

OBJECTIONABLE FEATURES:

REASON FOR RATING: Wasn't quite a 6, worse than out of turbulence though.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Influenced speed and bank attitude control somewhat.

CONFIGURATION ID: S02	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGLELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	5	**PILOT:**	G
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 146-148	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Relatively good about lateral-directional axes.

OBJECTIONABLE FEATURES: Want an attitude system. Static stability (longitudinal) close to neutral. Had to concentrate on maintaining attitude.

REASON FOR RATING: Moderately objectionable.

SPECIFICS:

TRIM: OK short term. Took awhile to settle down on where I wanted it trimmed. Used trim release exclusively.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: A little problem, had to really concentrate on closing attitude loop.

TURN COORDINATION: Not a problem, although turn rate in missed approach had some hesitancy, oscillatory. Maybe some sideslip coming in there, no big thing.

THRUST CONTROL: Good. Some coupling to roll now and then, but nothing outstandingly noticed.

TASK PERFORMANCE: Gained maybe 100 ft altitude in deceleration, didn't lead enough with collective. VOR acquisition to right, don't know why. VOR tracking good during descent. Small airspeed deviations during missed approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S02	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	7		**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	146-148	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Definite decrease in airspeed control.

REASON FOR RATING: Over performance limits.

SPECIFICS:

TRIM: Good. Used force-release.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Certainly worse in turbulence. Precision low, predictability not good.

TURN COORDINATION: Some disturbances back into lateral-directional handling qualities, turn rates hesitant and slightly unpredictable. Increased workload.

THRUST CONTROL:

TASK PERFORMANCE: All around decrease in performance. Gained altitude again in deceleration. VOR acquisition slightly better, tried harder. Descent not as good, some fairly large airspeed deviations during transitions.

EFFECTS OF TURBULENCE: Primarily in pitch to degraded speed control.

CONFIGURATION ID:	S02	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°	4½	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 170-172	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turns seemed smoother. Also transitions were smooth – easier to get to 60 knots, get right sink rate.

OBJECTIONABLE FEATURES: An awful lot of attention to nose attitude required; had to keep checking to maintain speed.

REASON FOR RATING: High scan rate required.

SPECIFICS:

TRIM: Did not do much. Had no static stability. Could stay right on neutral trim position with stick and just make inputs and finally get to your speed.

PITCH RESPONSE: Crisp enough, but do not know if response is going to put you on speed you want, may take several. Coupling did not bother me.

ROLL RESPONSE:

SPEED CONTROL: Fairly good, got off once. Predictability kind of a case of trial and error until get right attitude.

TURN COORDINATION:

THRUST CONTROL: Okay, no objectionable coupling.

TASK PERFORMANCE: Deceleration and VOR acquisition okay, tracking no special problem, descent no problem. Missed approach still most difficult, doing climb and turn and maintaining speed, rate of climb. Do use IVSI a lot as special control technique.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S01	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	6		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	170-172	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Smoother turn capability.

OBJECTIONABLE FEATURES: Things went to hell in a hand basket with turbulence in. Saw 200 ft altitude error in early part of approach.

REASON FOR RATING: Extensive compensation required.

SPECIFICS:

TRIM: Did not use. Just make changes off initial trim and then go back to position that existed.

PITCH RESPONSE: Inputs steady kind of thing, had to look at attitude, make small input, return to trim position.

ROLL RESPONSE: More difficult than pitch, but was best feature of configuration.

SPEED CONTROL: Not good. Not getting a cue, seem to get conflicting readings: might see speed high, on power and rate of climb, so have to do more power changes to resolve everything and then come back with power again, or just be patient and make slight changes, then back to trim.

TURN COORDINATION: Okay.

THRUST CONTROL: Coupling not objectionable.

TASK PERFORMANCE: Off on altitude early in flight, not certain why except got preoccupied in learning to fly thing in turbulence, scan got off.

EFFECTS OF TURBULENCE: Workload increase caused me to lose scan.

CONFIGURATION ID:	S02	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	4		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 192-194		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Predictable responses, well decoupled.

OBJECTIONABLE FEATURES: Constant small corrections.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Neutral static stability seen VFR, was not apparent at all IFR, didn't seem to create any problems.

TURN COORDINATION:

THRUST CONTROL: Coupling to roll and pitch seen VFR, did not create any problems IFR.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S02	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	5		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	192-194	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Same as with no turbulence — need for constant small corrections.

REASON FOR RATING: Considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

CONFIGURATION ID:	S02	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	M
LATERAL POSITION GRADIENT:	0.57 in./15°	4		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS: 299-301		SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Pitch caused by roll rate.

REASON FOR RATING: Minimal compensation, would be 3 for two pilots. But if had to do other things, would be a 4.

SPECIFICS:

TRIM: Nice to trim. Beeper used.

PITCH RESPONSE: Initial response crisp, liked better than previous configuration (S01). Predictability good, sensitivity adequate.

ROLL RESPONSE: Quite good.

SPEED CONTROL: Good until I make pitch errors. Speed to attitude relationship good, no problem with it in steady state speed control.

TURN COORDINATION: No problem.

THRUST CONTROL: Great.

TASK PERFORMANCE: Deceleration okay. Missed approach gives large inputs, large roll rates and those can give problem. Had large pitch attitude excursion coming out of missed approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	SC2	**PILOT RATING (IN TURBULENCE)**	5½	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	299-301	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Compensation between considerable and extensive because of way turbulence excites pitch excursions, detracts other axes too as I am forced to increase scan rate.

SPECIFICS:

TRIM: Can trim all, used beeper.

PITCH RESPONSE: More excursions.

ROLL RESPONSE: No change.

SPEED CONTROL: Fine again except in presence of large pitch control problems when speed falls off by about 8 knots. Is due to imprecision of pitch control.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Deceleration okay; tracking, descent no sweat. Missed approach, with large changes of flight condition, gave pitch excursion problem.

EFFECTS OF TURBULENCE: Mainly into pitch, ease with which large excursions are excited.

CONFIGURATION ID:	S02	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.57 in./15°	4		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS: 357-359		SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turn seemed smooth, most features good.

OBJECTIONABLE FEATURES: Speed excursions in go-around.

REASON FOR RATING: Compensation not too bad.

SPECIFICS:

TRIM:

PITCH RESPONSE: Fine.

ROLL RESPONSE: Fine.

SPEED CONTROL: Hard to catch on to how much nose-up attitude you really need to maintain speed in go-around.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Normal except for speed deviation in go-around.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S02	**PILOT RATING (IN TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	5	**PILOT:** K	
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 357-359	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Turbulence added workload, saw some speed transients I did not like.

SPECIFICS:

TRIM: Not using much — just riding with the little force that's necessary.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S03	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	-0.01 in./15°	4½		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	24-26	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Good turn coordination. Statically stable.

OBJECTIONABLE FEATURES: Constant small corrections to achieve desired attitude or bank angle.

REASON FOR RATING: It is between moderate pilot compensation and considerable pilot compensation.

SPECIFICS:

TRIM: No problems.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Good.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S03	**PILOT RATING (IN TURBULENCE)** 5	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:** H	
LATERAL POSITION GRADIENT: -0.01 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.71 in./15°	**RUNS:** 24-26	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Same as out of turbulence.

OBJECTIONABLE FEATURES: Same as out of turbulence.

REASON FOR RATING: Turbulence made workload a little bit higher.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Really not a lot of difference.

CONFIGURATION ID:	S03	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT:	-0.01 in./15°	5	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:** 30-32	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Could not keep airspeed well — of course, it is my first IMC approach today. Lack of attitude feedback loops made airspeed and altitude control not good. Bank angle not good in missed approach.

REASON FOR RATING:

SPECIFICS:

TRIM: Trim change laterally for 20 knots is more than longitudinally. Trimmability not good in pitch, roll. Hard to trim laterally. Looks like a little apparent negative dihedral effect.

PITCH RESPONSE: Good, but seemed easy to wander off in attitude even though it had positive stick-free stability. You have to keep your eye glued to attitude indicator.

ROLL RESPONSE: Good, some trimming problems.

SPEED CONTROL: Bad, particularly in transition (e.g., start descent).

TURN COORDINATION: No problem.

THRUST CONTROL: No problem, no apparent coupling to other axes.

TASK PERFORMANCE: Deceleration, VOR acquisition okay. Roll dynamics are such that I can do VOR tracking fairly well. Speed control bad during transition to descent. Hardest maneuver is missed approach, got too slow.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S03	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	7		**PILOT:**	C
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	30-32	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: None!

OBJECTIONABLE FEATURES: Tendency to sideslip to right — is combination of me pushing on pedal plus the turbulence exaggerating it. Think that lack of dihedral effect became problem. Airplane loose in roll, let it get away from me, got poor turn rate which caused me to lose pitch precision and airspeed went to pot too.

REASON FOR RATING: Wanted to cross over (not acceptable) line.

SPECIFICS:

TRIM: Degraded in turbulence — hard to hold onto.

PITCH RESPONSE: Pilot inputs not the problem, have good dynamics, but having to cope with external disturbances is problem. A lot of wandering in pitch and roll.

ROLL RESPONSE: Same problems as pitch.

SPEED CONTROL: Poor. Is reflection of inability to hold pitch attitude you want. Usually speed is good if have good pitch attitude control, which I did not have.

TURN COORDINATION: Hard to assess. Not necessarily a problem except for sideslip excursions caused by turbulence. Although sideslip, bank angle, and thus turn rate excursions were poor, cannot tie that to turn coordination.

THRUST CONTROL: Okay.

TASK PERFORMANCE: Some problem with altitude control during deceleration — easy to lose it if you don't have precise pitch control. VOR acquisition poorer because of lack of heading control caused by bank angle excursions, reflected in the descent both on pitch and rate-of-climb. Missed approach poor — bad speed control.

EFFECTS OF TURBULENCE: Roll axis, followed by pitch, then directionally. Sideslipping tendency was a constant problem.

CONFIGURATION ID: S03	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT: -0.01 in./15°	5	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.71 in./15°	**RUNS:** 176-179	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: Used lateral trim more, both beeper and mag brake. Trim adequate. Did not do much directional, did use others.

PITCH RESPONSE: Okay. Predictability not exactly as desired — had to make speed change in climbing turn, required a lot more nose-up, predictability not considered too good.

ROLL RESPONSE:

SPEED CONTROL: Difficult. Precision not good, had to change nose attitude more than expected. Had to concentrate more in setting up power. Off on speed more consistently than on other configurations.

TURN COORDINATION: Used more rudder, thought it all right, less wobbly and bobbly than other configurations.

THRUST CONTROL: More coupling with power change (axis not specified). Acceptable, but had to make compensating control input to make everything come out right when thrust changed.

TASK PERFORMANCE: VOR acquisition okay. Deceleration took a lot of control inputs to maintain altitude, workload item. No special comment on tracking or descent. Had less trouble in missed approach than with some others, although more consistently off speed.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S03	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5		**PILOT:**	K
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	176-179	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Turn very high workload, overbanking.

REASON FOR RATING:

SPECIFICS:

TRIM: Used lateral beeper, not much longitudinal, would use mag brake the few times longitudinal changed. No directional.

PITCH RESPONSE: Predictability a little difficult, seems to be a little spurt in there.

ROLL RESPONSE: Tendency to overbank, constantly correcting in roll.

SPEED CONTROL: Small attitude changes did not make speed move off at all, fairly speed stable for small changes. Looks like more than one attitude can give same speed.

TURN COORDINATION: Did not use rudders as much, I guess I let the ball slide out.

THRUST CONTROL: Was not as aware of compensating changes.

TASK PERFORMANCE: Same as out of turbulence, actually did a little better.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S03	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		PILOT:	M
LATERAL POSITION GRADIENT:	-0.01 in./15°	4	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS: 345-347	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Lateral OK even though it was neutral. Pitch/roll coupling pleasant. Precision laterally good.

OBJECTIONABLE FEATURES: Apparently slow response in pitch. Yaw to collective coupling noticed.

REASON FOR RATING:

SPECIFICS:

TRIM: Could trim well all three axes, used beeper.

PITCH RESPONSE: Initial response okay, except for feeling of a pitch threshold or long time-constant in pitch.

ROLL RESPONSE: No problem at all.

SPEED CONTROL: Simple, precise except when I let pitch task get out of hand.

TURN COORDINATION: Simple except in climbing turn, got some slip there, nothing excessive.

THRUST CONTROL: OK.

TASK PERFORMANCE: Satisfactory all through. Deceleration, VOR tracking no problem. Missed approach, get little pitch error coming in because of large bank angle, and therefore speed error is to be expected.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S03	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	6½		**PILOT:**	M
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:** 345-347		**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Very high workload, occassionally on borderline of control.

REASON FOR RATING: It is better than maximum tolerable pilot compensation, but 6 description is not sufficiently hard.

SPECIFICS:

TRIM: Was too busy to trim. Was a high frequency task.

PITCH RESPONSE: Same sort of initial threshold, does not help at all in turbulent IFR.

ROLL RESPONSE: Was not bothered. Am fairly used to aircraft with neutral static stability laterally. Was not a major problem at all.

SPEED CONTROL: Poor because of pitch control problems. Obtained large speed reduction once around descent, never could recover until top of overshoot maneuver.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Just adequate. Got to the right point at the right distance on the radial to start the missed approach, but it was a pretty crude approach. Did successful overshoot, so it has to be adequate.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S04	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		PILOT:	G
LATERAL POSITION GRADIENT:	-0.01 in./15°	6½	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS: 60-63	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Really none.

OBJECTIONABLE FEATURES: Getting speed errors very easy. Some problems with maintaining roll attitude, missed roll attitude stability, even thought at first lateral-directional characteristics looked good.

REASON FOR RATING: High pilot workload just to keep attitude where you want it, lack of speed stability made speed control task more complicated. Could do task, but I would not want to do this single-pilot IFR.

SPECIFICS:

TRIM: Using force release system — hard for my hand to use coolie hat on this stick.

PITCH RESPONSE: Dynamics good.

ROLL RESPONSE: Dynamics good.

SPEED CONTROL: A problem, almost unpredictable. Have to really watch pitch attitude, keep tight scan.

TURN COORDINATION: No problem — a little bit of coupling because of loose attitude loops.

THRUST CONTROL: Tendency to let pitch and roll attitude wander a bit with power inputs.

TASK PERFORMANCE: Deceleration similar to other configurations — have to really concentrate on holding pitch attitude to keep airspeed and altitude under control. VOR acquisition good, tracking not big problem except bank angle wandered a little. Have mentioned speed control — must concentrate on pitch attitude.

EFFECTS OF TURBULENCE:

AD-A093 654 NATIONAL AERONUATICS AND SPACE ADMINISTRATION MOFFET--ETC F/G 1/2
A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABI--ETC(U)
SEP 80 J V LEBACQZ, R D FORREST, R M GERDES

UNCLASSIFIED NASA-A-8125 NASA-TM-81188 NL

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CONFIGURATION ID:	S04	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		7	**PILOT:**	G
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	60-63	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Speed control worse, enough to push it over the line (inadequate), is intolerable for single pilot IFR, might lose it if had to tune radios or something.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Worse than before, enough to be inadequate.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Accentuates the difficulties described in no-turbulence case.

CONFIGURATION ID:	S04	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	-0.01 in./15°	4		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	94-97	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Comments missing.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S04	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5		PILOT:	H
LATERAL POSITION GRADIENT:	-0.01 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.01 in./15°	RUNS:	94-97	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Comments missing.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S04	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: -0.01 in./15°	5	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -0.71 in./15°	RUNS: 250-253	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Although airspeed control turned out to be OK, worked hard at it.

REASON FOR RATING:

SPECIFICS:

TRIM: Used mag brake quite a bit. Only used directional trim once to set up initial turn.

PITCH RESPONSE: Normal. Very fine control needed because of tendency to stray away in speed.

ROLL RESPONSE: Nothing unusual.

SPEED CONTROL: Lack of static stability noted VFR, but seemed fairly well behaved IMC. Still, worked hardest on this feature.

TURN COORDINATION:

THRUST CONTROL: Satisfactory.

TASK PERFORMANCE: May have gotten off more than 100 ft trying to get airspeed settled down. Had to bank in and out of turn, reestablish it during missed approached. Speed control pretty good throughout it.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S04	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		5½	**PILOT:**	K
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	250-253	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Airspeed slipped further out of bounds, got as much as 100 ft off on altitude at times.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Most difficult part of it. Got as low as 50, passed 70 momentarily. Couldn't take eyes away from pitch attitude for any length of time.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Seemed to require more nose high attitude to maintain speed in right-hand missed approach than I expected to.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S04	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:** M	
LATERAL POSITION GRADIENT: -0.01 in./15°	4	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.71 in./15°	**RUNS:** 374-376	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Amount of attention required for pitch and roll attitude. Paying attention to low frequency parameters would make me lose place in attitudes.

REASON FOR RATING: Desired performance was attained. It's a good 4 – want to call it a 3.8!

SPECIFICS:

TRIM: Good, used beeper.

PITCH RESPONSE: A little sluggish. Roll/pitch coupling pleasant.

ROLL RESPONSE:

SPEED CONTROL: Good in steady flight, crisp, no problem. Got bad if I let attitude get away from me, let errors build up.

TURN COORDINATION: No problem.

THRUST CONTROL:

TASK PERFORMANCE: Fine all the way through. Felt I had adequate performance: I can't get excited about plus/minus 10 knots deviation in this configuration.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S04	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	M
LATERAL POSITION GRADIENT:	-0.01 in./15°	4½		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	374-376	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Disturbances in pitch/roll required more attention, very high workload situation. Anxiety level up, confidence that I could maintain attitude was down.

REASON FOR RATING: Want to say desirable performance requires considerable compensation. I was working considerable, but performance was as desired.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Increase in workload, seen as increase in anxiety level, feel nearer the edge.

CONFIGURATION ID:	S05	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°	6½		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	40-42	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Did better than I'd anticipated.

OBJECTIONABLE FEATURES: Airplane loose directionally — get lots of right sideslip when you slow down. Workload high IMC, although could do job.

REASON FOR RATING:

SPECIFICS:

TRIM: Good all three axes.

PITCH RESPONSE: Satisfactory.

ROLL RESPONSE: Satisfactory.

SPEED CONTROL: Surprisingly good.

TURN COORDINATION: For rapid turns, some pedal required, but not really a problem IMC. Asymmetric response to rudder kicks noted in free run. Asymmetries of helicopter can be problem IFR. No problem in establishing climb and turn, which surprised me.

THRUST CONTROL: Satisfactory, coupling no big problem. Thrust inputs are relatively mild IMC, so could try to anticipate and cope with coupling.

TASK PERFORMANCE: As always, start climbing when I decelerate — have to lead with collective. VOR capture not good, didn't get it nailed. Tracking a problem because of tendency to sideslip to right, always have to fly crabbed, seems like crosswind from left. Sideslip characteristics an important handling quality because it complicates radial tracking, we would want an airplane that does not side slip easily. Transitions to descents and climbs not good, but trimmed descent relatively low workload. Missed approach surprisingly good, but high workload. Tended to use sideslip meter to help with this configuration.
NOTE: Sideslip meter covered for later evaluations.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	**PILOT RATING (IN TURBULENCE)**	7½	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	40-42	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: During missed approach, airspeed dropped down, got a large sideslip, airplane rolled, turn rate increased, overcontrolled dropping the wing, airspeed started to change more — thought on controllability came into my head. Bad combination — aircraft tends to wander and sideslip plus has significant dihedral and that interferes with pilot's primary task of turn control.

REASON FOR RATING: Controllability was of concern, so in between 7 and 8.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Turbulence showed up in directional coupling into bank angle causing turn control problems.

CONFIGURATION ID:	S05	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	4		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	45-47	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Had to keep making small corrections. Had to do more work with pedals to keep turn coordinated than I would like to.

REASON FOR RATING: Deficiencies minor but annoying.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S05	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	$4\frac{1}{2}$	**PILOT:**	H
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	**RUNS:** 45-47	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Some degradation in turn coordination.

CONFIGURATION ID: S05	PILOT RATING (NO TURBULENCE)	ROTOR: HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		PILOT: G
LATERAL POSITION GRADIENT: 0.57 in./15°	5½	FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	RUNS: 91-93	SCAS: RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed control OK.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: OK, but had to constantly reposition desired bank attitude. Couldn't trim it and sit there. Would take out big forces, then constantly move around.

PITCH RESPONSE:

ROLL RESPONSE: Some residual oscillatory problems. Constant attention in maintaining attitude.

SPEED CONTROL: Pretty good.

TURN COORDINATION: Seemed OK.

THRUST CONTROL: Coupling of collective into yaw apparent. Am now doing power changes more slowly, anticipating required change, to cope more easily with disturbance into directional.

TASK PERFORMANCE: Deceleration good. VOR tracking good, although workload high — too high for single-pilot IFR. Descent good, high workload. Some unsteadiness in turn rate for missed approach until I got aircraft squared away and trimmed. Only special control technique is being more careful with power application.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S05	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	$7\frac{1}{2}$	**PILOT:**	G
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	**RUNS:** 91-93	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: A lot of attitude disturbances, higher workload. If don't keep errors small, they can really get away from you.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL: Again tried not to be abrupt, but aircraft being disturbed in yaw all the time anyway.

TASK PERFORMANCE: All degraded.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		PILOT:	H
LATERAL POSITION GRADIENT:	0.57 in./15°	4½	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	RUNS: 107-109	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Directional, heading control.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Predictable.

ROLL RESPONSE: Predictable.

SPEED CONTROL:

TURN COORDINATION: Had to work on it.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	5		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	107-109	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Directional again, presents the most problems to me.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S05	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT: 0.57 in./15°	4	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	**RUNS:** 222-225	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: All relatively good except speed control.

OBJECTIONABLE FEATURES: Had to work harder at speed control, very quick changes with attitude.

REASON FOR RATING:

SPECIFICS:

TRIM: Used both systems, not much turn required. No rudder trim used.

PITCH RESPONSE: OK. Some question on predictability.

ROLL RESPONSE: Tend to want to overcontrol unless use beep trim. Tend to roll in further than I mean to.

SPEED CONTROL: Most difficult characteristic.

TURN COORDINATION: Not bad, could set up stable turn and continue it pretty well.

THRUST CONTROL: OK — adequate response, no objectionable coupling.

TASK PERFORMANCE: Overshot altitude on go-around, was concentrating too much on heading. Rest normal except speed control.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	4		PILOT:	K
LATERAL POSITION GRADIENT:	0.57 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	RUNS:	222-225	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Most things looked pretty good.

OBJECTIONABLE FEATURES: Speed control a little better except lost 10 knots in transition to level flight after go-around, didn't make enough attitude change with power change. Turns more of a problem in turbulence, ratchety.

REASON FOR RATING:

SPECIFICS:

TRIM: No problem, both systems used.

PITCH RESPONSE: OK. Relationship to speed change is a little hard to catch on to.

ROLL RESPONSE: Didn't see any coupling to anything else.

SPEED CONTROL: Better, but still a little problem.

TURN COORDINATION: Not really using rudder. If I were really coordinating turns and making a real effort on rudder, might see more coupling to roll.

THRUST CONTROL: Good.

TASK PERFORMANCE: Got off on altitude (100 ft) — I think that's scan.

EFFECTS OF TURBULENCE: Not much effect.

CONFIGURATION ID: S05	PILOT RATING (NO TURBULENCE)	ROTOR: HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		PILOT: K
LATERAL POSITION GRADIENT: 0.57 in./15°	4½	FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	RUNS: 316-318	SCAS: RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed held relatively steady, for good periods of time.

OBJECTIONABLE FEATURES: A lot of hunting in roll, thought maybe I was out of trim.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE: Took a lot of my attention.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	**PILOT RATING (IN TURBULENCE)**	5	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	316-318	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Roll gave most workload, hunting back and forth, requires quite a bit of attention.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE: Seemed super sensitive. Couldn't use rudder — any tiny touch of rudder would throw you into what seemed like an unwarranted amount of bank, increased bank angle when you tried to center the ball.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Acceptable.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	M
LATERAL POSITION GRADIENT:	0.57 in./15°	5		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	RUNS:	348-350	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Not many. Just a mediocre machine.

OBJECTIONABLE FEATURES: Lively Dutch roll, looseness in yaw in combination with good, marked sideslip stability (laterally). Easily excited Dutch roll gives lateral control problem and directional control problem. Took so much of my attention that other axes got sloppy.

REASON FOR RATING: Rating it for worst part of task that I see, which was the climbout.

SPECIFICS:

TRIM: Was able to trim and did trim considerably on initial approach and descent.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Good until climbout, then went bad.

TURN COORDINATION: Very poor. Every time you roll back on, you develop large sideslip and it reacts with large dihedral and away we went. Turn coordination very difficult.

THRUST CONTROL:

TASK PERFORMANCE: Approach itself not a big problem, moderate workload. Tracking easy to accomplish and quite good. Major power change and attitude change required for missed approach are what showed up the evil in this animal.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S05	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	6½		**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	348-350	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Dutch roll excitation such that lateral-directional control took much of my attention. To make machine workable, had very high mental workload, very high scan rate, considerably more control activity than I like. Lateral-directional task extremely demanding, caused degradation in other axes tasks.

REASON FOR RATING: Unpleasant: flyable, probably safe, but damn scarey. Always have problem with 6-7 break. Compensation was tolerable, performance was adequate, but I felt aircraft had major deficiencies.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Good, not a problem.

TURN COORDINATION: Same comments as smooth air but of course more difficult, more excitation. Even in steady turn slip angle was going plus/minus 10°. Roll interaction went with it, made for very sloppy machine.

THRUST CONTROL:

TASK PERFORMANCE: Acceptable accuracy, but very high workload.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S06	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.03 in./15°	$6\frac{1}{2}$	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 74-76	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed control, rate of descent, rate of climb.

OBJECTIONABLE FEATURES: Lateral-directionally poor, showed up in most aspects of the task.

REASON FOR RATING:

SPECIFICS:

TRIM: Didn't trim up as well laterally as did longitudinally, large requirement both directionally and laterally. Wouldn't hold bank angle very long, constant wandering directionally.

PITCH RESPONSE: Harmony, breakout, forces, responses OK.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL:

TURN COORDINATION: Very poor. Tendency to overcontrol directionally. Roll into bank, get sideslip, get rolling moment, difficult to control bank and thus turn and thus tracking.

THRUST CONTROL: OK. Some coupling evident in roll and directionally.

TASK PERFORMANCE: Deceleration not bad, airplane holds speed pretty well. VOR acquisition hindered by lateral-directional problems. Same with VOR tracking and descent — power change would precipitate lateral directional problems. Turn rate in missed approach irregular, although speed and rate of climb control good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S06	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	7		PILOT:	G
LATERAL POSITION GRADIENT:	0.03 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	74-76	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Biggest problem is that any transitions from trimmed flight — power is big one, rolling in and out of turns — generates sideslip, get rolling moment, becomes a problem.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Poor this time because of turbulence.

TURN COORDINATION: A mess. Lots of wandering.

THRUST CONTROL: OK, but coupling to yaw can really be seen now.

TASK PERFORMANCE: VOR tracking and deceleration worse. Problem with commencing descent, level-off, and missed approach.

EFFECTS OF TURBULENCE: Induced a lot of wandering around of pitch, roll, yaw.

CONFIGURATION ID:	S06	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		5½	**PILOT:**	H
LATERAL POSITION GRADIENT:	0.03 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	125-127	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Collective fairly well decoupled.

OBJECTIONABLE FEATURES: Yaw axis control.

REASON FOR RATING: Was really working! Could have gotten adequate performance with worse configuration, but not a whole lot worse. Wouldn't want to take it IFR.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Divergent long period oscillation on longitudinal noted VFR. (No comments IMC).

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S06	**PILOT RATING (IN TURBULENCE)** 5½		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.03 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	125-127	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Couldn't tell if turbulence made workload that much harder.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S06	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	4½	**PILOT:**	K
LATERAL POSITION GRADIENT: 0.03 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 259-262	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Held speed and rate of climb well.

OBJECTIONABLE FEATURES: Things got disturbed when I made power changes.

REASON FOR RATING: Considerable compensation.

SPECIFICS:

TRIM: Primarily using mag brake, occasionally beeper.

PITCH RESPONSE: Adequate.

ROLL RESPONSE: Still having problems in turns, can't get smooth coordinated turns set up. Seem to have this problem on all configurations.

SPEED CONTROL: Good — required effort but was good, stayed relatively stable.

TURN COORDINATION: Ratchety, hard to get coordinated.

THRUST CONTROL: Gives you some feedback and causes you to get off on speed and things.

TASK PERFORMANCE: No problems other than power changes in transitions.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S06	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5		PILOT:	K
LATERAL POSITION GRADIENT:	0.03 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	259-262	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Saw speed changes with power changes. Also slight changes in speed made pretty fair changes in climb rate.

REASON FOR RATING: A little shady on this one.

SPECIFICS:

TRIM: Didn't use much, just held little tiny bit of pressure required. Didn't seem necessary to trim out.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Normal. Only problem was unwanted changes in speed and rate of climb when power changed.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S06	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	M
LATERAL POSITION GRADIENT: 0.03 in./15°	$4\frac{1}{2}$	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 377-379	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed stability, pitch attitude control.

OBJECTIONABLE FEATURES: Looseness in sideslip which couples into roll, get lateral excitation problem. Large excursions in sideslip.

REASON FOR RATING: Performance adequate, compensating considerably. It's a 4 with high workload. Had feeling that aircraft control itself could have been problem, although it wasn't.

SPECIFICS:

TRIM: Good longitudinally. Could also trim well laterally.

PITCH RESPONSE: OK.

ROLL RESPONSE: OK.

SPEED CONTROL: Good.

TURN COORDINATION: Hideous. Possible to achieve but at the expense of some hard work.

THRUST CONTROL:

TASK PERFORMANCE: Adequate, pretty close to desired all through.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S06	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots	6½	**PILOT:**	M
LATERAL POSITION GRADIENT: 0.03 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 377-379	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed OK.

OBJECTIONABLE FEATURES: Scan pattern very rapid, much more rapid than one could do for prolonged flight. Yaw and roll attitude require a lot of attention, cross-couple and easily excited by turbulence. Large slip angles which I don't like.

REASON FOR RATING: Adequate performance attainable, which excludes a 7 (sic). Was close to maximum tolerable compensation. Couldn't have kept that kind of work rate up for long.

SPECIFICS:

TRIM: Same comments as before.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Got into ballpark figures, after that just flew attitudes and let speed do what it wants, didn't really try to control it very well — didn't have enough attention to do that. Besides, can't get awfully excited about 10 knots in a helicopter.

TURN COORDINATION: Difficult due to turbulence, was doing my best.

THRUST CONTROL:

TASK PERFORMANCE: Acceptable in terms of departures from desired, but aircraft did go through large attitude excursions at times.

EFFECTS OF TURBULENCE: Definitely was prime exciter of lateral-directional.

CONFIGURATION ID: S07	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.57 in./15°	7½	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	**RUNS:** 33-36	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Pilot-induced attitude disturbances with resulting flightpath, airspeed, and altitude departures.

REASON FOR RATING:

SPECIFICS:

TRIM: Poor. Once get attitude stabilized, can trim it for short period, but airplane doesn't stay still long so you find yourself trying to retrim it again. Problem in all three axes — directional also degraded with this one.

PITCH RESPONSE: Pitch statics looks bad — neutral. Dynamics good — almost too good, could displace airplane too easily, it could get away from you because of high response of system.

ROLL RESPONSE: Roll axis constantly disturbed by apparent dihedral effect. Seemed to be strong but never could get sideslip to settle down and make this determination there.

SPEED CONTROL: Poor precision and poor predictability. Couldn't keep pitch attitude where I wanted it.

TURN COORDINATION: Directional statics look bad. Coordination really crummy IMC. Large sideslip angles a problem.

THRUST CONTROL: All right. Had feeling that yaw problem was being aggravated by power inputs, although didn't see any particular coupling in free run.

TASK PERFORMANCE: All parts poor. In missed approach, gained all kinds of airspeed, banking poor, turn rate all over the place. Just very bad.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S07	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		8	PILOT:	G
LATERAL POSITION GRADIENT:	0.57 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	RUNS:	33-36	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: I can't take any more of that! A couple of times started to lose airplane, large sideslip and airplane wanting to roll and kind of pitch at same time.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Turbulence makes everything talked about before even worse. Lack of static stability (longitudinal) and degraded directional seemed worse. Not a heck of a lot worse in turbulence, it's still bad either way.

CONFIGURATION ID: S07	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	5	**PILOT:**	H
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	**RUNS:** 122-124	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Collective apparently well decoupled.

OBJECTIONABLE FEATURES: Had problem keeping ball centered.

REASON FOR RATING: Considerable pilot compensation.

SPECIFICS:

TRIM: Caused problem.

PITCH RESPONSE: Continuous small corrections to hold attitude.

ROLL RESPONSE: Continuous small corrections to hold bank.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S07	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5½		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	122-124	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Workload higher, performance not as good. Could have gotten adequate performance with worse configuration.

SPECIFICS:

TRIM: Didn't do as well holding trim.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Didn't control as well.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Aggravated control of attitude and yaw trim.

CONFIGURATION ID:	S07	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°	5½	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:** 180-182	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Good response to power for altitude tracking.

OBJECTIONABLE FEATURES: Bad turn control and its effect on pitch control. Seemed to get behind aircraft in scan, got below 50 knots in missed approach.

REASON FOR RATING: Believe I'd accept more compensation, but not too much more.

SPECIFICS:

TRIM: Used frequently, mostly mag brake.

PITCH RESPONSE: Hunt-and-peck to get correct readings on all instruments — both airspeed and IVSI. Not very predictable. Pitch changes were necessary in missed approach maneuver more than expected.

ROLL RESPONSE:

SPEED CONTROL: Poor predictability.

TURN COORDINATION: Kind of poor. Turns felt weird in cockpit. Not spending much time looking at ball, turns were not smooth.

THRUST CONTROL: Saw some coupling on free run, but didn't stick out as objectionable IMC.

TASK PERFORMANCE: Difficult to make all the transitions and get things settled down. Speed control generally acceptable, did get below 50 knots once and I made fairly radical change to get it back,

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S07	**PILOT RATING (IN TURBULENCE)**	5½	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	180-182	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Power response: pretty immediate up or down response.

OBJECTIONABLE FEATURES: Hard to get right nose attitude in right hand turn. Could not find constant turn position, constantly controlling the aircraft into and out of turns, which feeds back into pitch attitude.

REASON FOR RATING:

SPECIFICS:

TRIM: Trimmed frequently with mag brake, needed fast change.

PITCH RESPONSE: Not too predictable.

ROLL RESPONSE:

SPEED CONTROL: Difficult, requires a lot of attention, would wander off when I changed power.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Missed approach most difficult. May be banking steeper, making it more difficult on myself.

EFFECTS OF TURBULENCE: Saw no increase in workload.

CONFIGURATION ID:	S07	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°	8		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	351-353	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Attitude and particularly heading control very difficult. Speed control bad, large slip angles. Directional and roll looseness.

REASON FOR RATING: Considerable compensation required for control at moments in that run. Didn't have enough capacity to do better job, saturated on several occasions.

SPECIFICS:

TRIM: OK initially, but didn't even try once aircraft became dynamic.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Awful.

TURN COORDINATION: Next to impossible.

THRUST CONTROL: Didn't have time to look at.

TASK PERFORMANCE: Crude, subject to very large excursions.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S07	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		10	**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	351-353	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Major flightpath changes and attitude changes really posed major problems, sideslip got away in missed approach.

REASON FOR RATING: Lost control in missed approach, lost track of sideslip.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S08	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	4½	**PILOT:** H	
LATERAL POSITION GRADIENT: 0.03 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 134-136	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: Problems with pitch and roll trim, mainly yaw.

PITCH RESPONSE: Had to make constant corrections.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S08	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5		PILOT:	H
LATERAL POSITION GRADIENT:	0.03 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	134-136	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Pitch response fairly good.

OBJECTIONABLE FEATURES: Turbulence messed up roll, yaw trim gave me biggest problem.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Influenced roll.

CONFIGURATION ID: S08	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:** G	
LATERAL POSITION GRADIENT: 0.03 in./15°	7	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 140-142	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Poor airspeed control, was aware of coupling coming in because of relaxed directional stability.

REASON FOR RATING: Borderline tolerable workload, went over my performance limits a couple of times.

SPECIFICS:

TRIM: Seemed OK very short term. Used rate trim for directional.

PITCH RESPONSE: Good, but had to constantly use inputs to compensate for pilot-induced disturbances.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL: Poor — got down to 40 knots once.

TURN COORDINATION: Airplane directionally asymmetric statically, turn coordination bad, turn rates unsteady in missed approach, was pushing pedals, didn't feel in balanced flight.

THRUST CONTROL: Good, but coupling to all axes seemed bad.

TASK PERFORMANCE: Some climbing and descending during deceleration. VOR acquisition not bad, although crossed VOR station off to one side. VOR tracking during descent pretty good once descent rate got established. Bad speed control in level-off. Missed approach a little shoddy looking. Speed control pretty bad compared to S01.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S08	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.03 in./15°	$7\frac{1}{2}$		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	140-142	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: None.

OBJECTIONABLE FEATURES: Fell asleep on getting back to heading after missed approach, had to make quick correction, can really reveal unforgiving characteristics of poor control system like this one. I was able to get back, but airspeed went way down, dropped off, really a poor characteristic.

REASON FOR RATING: Reaching the point where controllability maybe was in question.

SPECIFICS:

TRIM: Trims nicely in 60 knots, 1000 fpm descent.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Poor.

TURN COORDINATION:

THRUST CONTROL: Collective into yaw noticed. Would change heading and I would then have bank control problems getting heading back. Coupling eats you up when you also have turbulence to contend with.

TASK PERFORMANCE: Deceleration a little worse in holding altitude. VOR acquisition off to one side — feel airplane is sideslipping. Maybe sideslip is less in descent and that's why VOR tracking better there. Descent was best part of handling qualities. Some gyrations in transitions to and from descent due to coupling. Missed approach not good: one to right may be easier than to left because of helicopter asymmetrics.

EFFECTS OF TURBULENCE: If aircraft is already poor, this level of turbulence doesn't degrade it much. If I'd hit a big gust and scared myself, might have been 8 or 9. Largest effect in pitch axis.

CONFIGURATION ID:	S08	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	-0.03 in./15°	6		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	312-314	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Touchy in both pitch and roll. Some coupling with power changes.

REASON FOR RATING: Takes a fast scan.

SPECIFICS:

TRIM: Difficult. Trimming a constant process, one is required to make constant attitude changes. Used mag brake only.

PITCH RESPONSE: Responses prompt, but aircraft tended to wander off.

ROLL RESPONSE:

SPEED CONTROL: Difficult because of heading and attitude changes.

TURN COORDINATION: Seemed better, turn relatively smooth.

THRUST CONTROL:

TASK PERFORMANCE: Tolerated more change in airspeed than on previous approaches, but don't believe I got outside of a 10 knot band.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S08	**PILOT RATING (IN TURBULENCE)** 5½	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:** K	
LATERAL POSITION GRADIENT: 0.03 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	**RUNS:** 312-314	**SCAS:** RATE	

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Seemed easier than in smooth air.

OBJECTIONABLE FEATURES: Still touchy, lot of control inputs necessary.

REASON FOR RATING:

SPECIFICS:

TRIM: Some of the time just held force, other times just hold mag brake button down. No beeper used.

PITCH RESPONSE: Same comments.

ROLL RESPONSE: Same comments.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Was better than out of turbulence. Speed excursions not so frequent. Overshot final missed approach altitude by 100 ft, probably my fault.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	PILOT RATING (NO TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	4		PILOT:	H
LATERAL POSITION GRADIENT:	0.52 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	RUNS:	54-56	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Note: Vibration in cab caused by unknown source gave ride qualities problem.

REASON FOR RATING: Thought it needed improvement. Want to call it worse than 4, but vibration may be affecting me.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	PILOT RATING (IN TURBULENCE)	ROTOR: TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	$4\frac{1}{2}$	PILOT: H
LATERAL POSITION GRADIENT:	0.52 in./15°		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	RUNS: 54-56	SCAS: RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Response fairly predictable.

OBJECTIONABLE FEATURES: Constant small corrections required to keep attitude and bank angle.

REASON FOR RATING: Turbulence increased workload a little bit.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Some pedal required, but not excessive.

THRUST CONTROL: No coupling noticed.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	PILOT RATING (NO TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	G
LATERAL POSITION GRADIENT:	0.52 in./15°	6		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	RUNS: 87-90		SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Airplane is a little unpredictable. Have to keep real tight control over small errors, or they build up and get away from you. Recovery from a small error results in a larger error, a tendency to diverge. Speed control a problem even in level segments — maybe a timesharing effect because of diverting attention to poor lateral directional.

REASON FOR RATING: Is on boundary of unacceptable because of tendency to diverge, maximum workload. Did better just with 2 runs instead of usual 1.

SPECIFICS:

TRIM: Good short term. Used force-release trim.

PITCH RESPONSE: Noticed yaw due to pitch in free run, but not for smaller inputs used IFR.

ROLL RESPONSE: OK, predictable, good response. Felt I was inducing some sideslip in approaches. Don't have B-meter now, miss it for cases like this with poor sideslip characteristics. Maybe such meters should be a requirement.

SPEED CONTROL: Poor, partly because attention was saturated with lateral-directional problems.

TURN COORDINATION: Didn't seem to be a big problem, but I was having lateral-directional problems so it was obviously a factor.

THRUST CONTROL: OK. Was sensitive to yaw due to collective, however, disturbed aircraft to where it interfered with turn control and VOR tracking.

TASK PERFORMANCE: Lost 100 ft altitude during deceleration, don't know why. VOR acquisition poor, never got needle centered, I think because of weak directional stability or poor lateral directional characteristics. Yawed off when dropped collective for descent. Disappointing performance, high workload. Missed approach poor at first, hunting for right bank angle. Feel that poor directional characteristics causing problem — turn rate and speed control.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	$6\frac{1}{2}$		**PILOT:**	G
LATERAL POSITION GRADIENT:	0.52 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	**RUNS:**	87-90	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Right on the boundary.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	PILOT RATING (NO TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.52 in./15°	6		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	RUNS:	232-234	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Nothing.

OBJECTIONABLE FEATURES: Pitch attitude change. Got off on speed, behind my power and scan, several times. Need higher pitch attitude to maintain 60 knots in climb than you do in cruise.

REASON FOR RATING: Pretty extensive compensation for adequate performance.

SPECIFICS:

TRIM: Didn't do much, needed it right away, used mag brake.

PITCH RESPONSE: Adequate if you know where to put it. Airplane requires different nose attitude when you go into a turn.

ROLL RESPONSE:

SPEED CONTROL: Poor.

TURN COORDINATION: OK, average.

THRUST CONTROL: Some coupling problems, but unsure of new power settings with this rotor type.

TASK PERFORMANCE: Average. Got rusty in a couple of places, possibly as a result of power changes.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S09	PILOT RATING (IN TURBULENCE)	ROTOR: TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	6 1/2	PILOT: K
LATERAL POSITION GRADIENT:	0.52 in./15°		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT:	-0.33 in./15°	RUNS: 232-234	SCAS: RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Not certain how much is me just fouling up and how much is configuration. Got all fouled up several times, new power settings are having some influence. Big problem was finding right pitch attitude for cruise with various power settings to control speed properly.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Really poor. Make slight change, almost can't believe you have to make another one to get that airspeed needle to move in the direction you want. That's real difficult.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S10	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.02 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.02 in./15°	8	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.34 in./15°	**RUNS:** 71-73	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Classically bad in all respects. PIO tendencies around zero in pitch and roll.

REASON FOR RATING:

SPECIFICS:

TRIM: Never could — always moving controls around.

PITCH RESPONSE: Fairly easy to induce PIO.

ROLL RESPONSE: Fairly easy to induce PIO.

SPEED CONTROL: Large excursions with power changes.

TURN COORDINATION: Bad. A couple of times the sideslip meter went off the peg.

THRUST CONTROL:

TASK PERFORMANCE: Poor all around.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S10	PILOT RATING (IN TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots	8½		PILOT:	G
LATERAL POSITION GRADIENT:	0.02 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./15°	RUNS:	71-73	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: General comment: power setting for 60 and 80 knots about the same, means that reducing power for level off after climb won't slow you down like hingeless rotor, increases pilot workload.

EFFECTS OF TURBULENCE: Just makes it worse all around.

CONFIGURATION ID: S10	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.02 in./20 knots		**PILOT:**	H
LATERAL POSITION GRADIENT: 0.02 in./15°	6	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.34 in./15°	**RUNS:** 104-106	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Relative lack of collective to yaw coupling.

OBJECTIONABLE FEATURES: Didn't even like VFR! A lot of longitudinal to directional coupling. Big problem with heading control.

REASON FOR RATING: Might have achieved adequate performance with a little worse airplane, but I'm not sure.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S10	PILOT RATING (IN TURBULENCE)	6½	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.02 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./15°	RUNS:	104-106	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Heading control.

REASON FOR RATING: Maximum tolerable pilot compensation. Over a period of time it would possibly have been more than I could handle.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S10	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** TEETERING	
LONGITUDINAL POSITION GRADIENT: -0.02 in./20 knots		**PILOT:** G	
LATERAL POSITION GRADIENT: 0.02 in./15°	7	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -0.34 in./15°	**RUNS:** 209-212	**SCAS:** RATE	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: First part of run good up to level-off.

OBJECTIONABLE FEATURES: Directional stability went to pot below 60 knots, increased sideslip, which caused more airspeed drop. Happened at level-off after missed approach.

REASON FOR RATING:

SPECIFICS:

TRIM: Good short term.

PITCH RESPONSE: Good, but a bit abrupt. Harmony to roll not good. Was not factor IFR.

ROLL RESPONSE:

SPEED CONTROL: Fine until level-off at end of missed approach airspeed built up. Longitudinal stability was either neutral or slightly negative.

TURN COORDINATION: Not a problem until below 60 knots. Turn entries looked fine, rollout had some problem after missed approach, perhaps caused by sideslip form level-off.

THRUST CONTROL: Coupling into yaw a factor below 60 knots.

TASK PERFORMANCE: Looked good up until level-off after missed approach. Tracking good up to that point.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S10	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots		7½	**PILOT:**	G
LATERAL POSITION GRADIENT:	0.02 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./15°	**RUNS:**	209-212	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Level-off at end of missed approach again caused speed to bleed way off, lots of sideslip.

REASON FOR RATING:

SPECIFICS:

TRIM: Fine. Used mag brake.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: Seemed slightly unstable so turbulence disturbances caused divergence. Not predictable.

TURN COORDINATION: No problem per se.

THRUST CONTROL: OK. Yaw moment due to collective a problem.

TASK PERFORMANCE: Initial VOR tracking off because of distraction in cockpit, not because of flying qualities. Deceleration mediocre. Tracking not bad because heading control OK if I stayed at 60 knots. Had to crab sometimes, must have been sideslipping. Missed approach entry and establishment not too bad, but level-off at end poor. Speed control worse than smooth air case.

EFFECTS OF TURBULENCE: Performance deteriorated, particularly in disturbing speed, some in yaw.

CONFIGURATION ID:	S10	PILOT RATING (NO TURBULENCE)	ROTOR: TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots	5	PILOT: K
LATERAL POSITION GRADIENT:	0.02 in./20 knots		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./20 knots	RUNS: 269-271	SCAS: RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turns seemed a little better coordinated.

OBJECTIONABLE FEATURES: Can't catch on to how much nose-up attitude required in turns, at least right hand. Airspeed got off more than 10 knots in turn.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Adequate. Not much coupling.

ROLL RESPONSE:

SPEED CONTROL: Sloppy at times, particularly during transitions.

TURN COORDINATION: Seemed better.

THRUST CONTROL: Satisfactory.

TASK PERFORMANCE: Got sloppy. Things were a little abrupt at certain points in approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S10	PILOT RATING (IN TURBULENCE)	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.02 in./20 knots	5	PILOT:	K
LATERAL POSITION GRADIENT: 0.02 in./20 knots		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -0.34 in./20 knots	RUNS: 269-271	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: All comments the same.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S10	PILOT RATING (NO TURBULENCE)	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots		PILOT:	H
LATERAL POSITION GRADIENT:	0.02 in./15°	5	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./15°	RUNS: 324-326	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Responses predictable except in yaw.

OBJECTIONABLE FEATURES: Had a lot of trouble with yaw. Also required constant small corrections pitch/roll.

REASON FOR RATING: Needs more improvement than previous configuration (S26). Considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE: Predictable. Neutral longitudinal stability didn't bother me IFR.

ROLL RESPONSE: Predictable. Neutral lateral stability no problem IFR.

SPEED CONTROL:

TURN COORDINATION: Directional stability too weak. Yaw control was primary objectionable feature.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S10	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.02 in./20 knots		6	**PILOT:**	H
LATERAL POSITION GRADIENT:	0.02 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.34 in./15°	**RUNS:**	324-326	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Pitch, roll predictable.

OBJECTIONABLE FEATURES: Workload too high, particularly yaw.

REASON FOR RATING: Adequate performance just barely obtainable. A couple of times I didn't quite attain adequate performance in an axis, but it wasn't enough to call it worse than a six.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S11	PILOT RATING (NO TURBULENCE)	ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.48 in./20 knots		PILOT:	C
LATERAL POSITION GRADIENT:	0.66 in./15°	8½	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.20 in./15°	RUNS: 199-205	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Speed stability is nice, although couldn't take full advantage of it because of lateral-directional weaknesses.

OBJECTIONABLE FEATURES: Lateral-directional axes! Control of heading, yaw moments due to collective.

REASON FOR RATING:

SPECIFICS:

TRIM: Good. Could even trim out sideslip because of high dihedral effect, could feel it in lateral control.

PITCH RESPONSE: Saw pitch bobble VMC, not noticed IMC.

ROLL RESPONSE: Good.

SPEED CONTROL: Good control potential, predictability, but need better lateral-directional to look at it.

TURN COORDINATION: Bad.

THRUST CONTROL: Control good, coupling into directional axis really bad. If I applied or reduced power, big directional disturbances resulted, destroyed heading control.

TASK PERFORMANCE: VOR acquisition mediocre — not too bad because power wasn't changed. Deceleration OK for same reason. VOR tracking not good, in descent had sideslip all over the place, had to look for trim. Level-off same. Missed approach really bad, uneven turn rate, uneven climb rate, poor speed control. Special control technique: have to make collective changes very gradually, rapid ones kick airplane into unacceptable conditions.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S11	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.48 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.66 in./15°	9		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.20 in./15°	**RUNS:**	199-205	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Same only worse.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Did make job harder, airplane worse.

CONFIGURATION ID:	S11	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.48 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.66 in./15°	8		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.20 in./15°	**RUNS:** 235-239		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: None.

OBJECTIONABLE FEATURES: A lot of coupling among various axes — collective to pitch and roll. Another problem was directional control, heading wanted to wander all over the lot.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Just tried to hold wings level and use whatever pedal was required to hold heading, pay no attention to ball. Didn't try to trim yaw at all.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S11	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.48 in./20 knots	8		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.66 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.20 in./15°	**RUNS:** 235-239		**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Same degree of difficulty.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: No new problems with it.

CONFIGURATION ID:	S13	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	6		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 15-18		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Good directional stability, good longitudinal position stability, although latter wasn't really that valuable.

OBJECTIONABLE FEATURES: Lack of force gradients.

REASON FOR RATING: Lack of force gradients very objectionable deficiency, extensive pilot compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S13	PILOT RATING (IN TURBULENCE) 6	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		PILOT:	H
LATERAL POSITION GRADIENT: 0.57 in./15°		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	RUNS: 15-18	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Same as out of turbulence.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Lack of force stick reference position is such that turbulence didn't make much difference.

CONFIGURATION ID:	S13	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°	5½		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	110-112	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: All performance aspects looked good.

OBJECTIONABLE FEATURES: Having to hold up stick is tiring, lack of friction or gradient undesirable.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Satisfactory. Lack of force gradient makes controller incompatible with controlled element.

ROLL RESPONSE: Satisfactory.

SPEED CONTROL: Good. Lots of workload, but could hold attitude well.

TURN COORDINATION: No problem, some sideslip to right noticed in free run.

THRUST CONTROL: Coupling a little problem. Segments involving power changes harder to contend with, without gradient. Friction would help, gradient does assist in reducing or compensating coupling.

TASK PERFORMANCE: Deceleration, VOR tracking good. Some problems with transitions for descent because of power changes. Missed approach same, comfortable once in it. Speed control considered good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		7	**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	110-112	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Continual disturbances from turbulence on top of those from power changes is too much; friction or gradient could help in relieving or reducing pilot workload.

REASON FOR RATING: Can live with airplane in smooth air, but start externally disturbing it and that's it. Maybe was too nice to it in smooth air, should make it 5½.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: More of a problem holding speed.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Didn't do as good a job rolling out for VOR tracking. I think sideslip was wandering around, causing tracking problem.

EFFECTS OF TURBULENCE: Noticeable degradation in tracking performance.

CONFIGURATION ID:	S13	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°	7	**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 143-145	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Only good thing was we made it through approach!

OBJECTIONABLE FEATURES: Lack of gradient or friction, strain of just holding stick where you want it and having to scan constantly to attitude indicator. If you don't scan attitude, it will lift off and airspeed went to pot, diverged rapidly. Scan pattern required is unacceptable, keeping you on attitude indicator all the time. Doing a simultaneous task like rolling out and changing power is very difficult to perform precisely.

REASON FOR RATING:

SPECIFICS:

TRIM: Not applicable.

PITCH RESPONSE: Considerations like initial response, predictability, final response, sensitivity all good.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL: Poor because of lack of precision in pitch, self induced attitude changes.

TURN COORDINATION: Didn't seem to be a problem, although friction or gradient on pedals might have helped do a better job.

THRUST CONTROL: Good. Coupling a little problem because lack of stick centering made contending with it a little harder.

TASK PERFORMANCE: Deceleration: poor attitude control. VOR acquisition not as precise. Tracking degraded, descent took longer to get squared away, had to constantly watch attitude indicator. Missed approach difficult, high workload item keeping turn rate going and watching for deviation.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S13	**PILOT RATING (IN TURBULENCE)** 7½	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.57 in./15°		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT: -0.72 in./15°	**RUNS:** 143-145	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Same as in smooth air. Adding external disturbances to pilot-induced ones means was constantly using control system, constantly in motion, high workload.

REASON FOR RATING: Controllability starting to become a question.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: A little poorer, worked harder.

TURN COORDINATION: No difference in turbulence seen.

THRUST CONTROL:

TASK PERFORMANCE: Degraded all around. A little harder to fly, a little less performance.

EFFECTS OF TURBULENCE: Just generally disturbed desired track of airplane.

CONFIGURATION ID:	S13	PILOT RATING		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	(NO TURBULENCE)		PILOT:	K
LATERAL POSITION GRADIENT:	0.57 in./15°	5		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS:	173-175	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Don't ever have to use trim!

OBJECTIONABLE FEATURES: Very very constant rapid scan. Very aware that any motion of hand will change something, creates workload in mind.

REASON FOR RATING: Moderately objectionable, considerable pilot compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE: Plenty responsive — it's a wet noodle. Get immediate response, must keep motions small. Pretty good predictability. Used series of small changes but it didn't seem too awfully difficult to get to a speed once you were concentrating.

ROLL RESPONSE: Responsive, didn't see any coupling.

SPEED CONTROL: Somewhat more difficult but it seemed to change (back) a little faster than other configurations (S01, S02). Saw more deviation early in run than in most runs.

TURN COORDINATION:

THRUST CONTROL: No coupling apparent. Makes go-around easier.

TASK PERFORMANCE: Go-around seemed a bit easier. Changed power before started (turn). Special control technique is to keep inputs as tiny as possible, make changes with several small motions.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5½		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	173-175	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Lack of need to use trim.

OBJECTIONABLE FEATURES: Takes longer to get conditions you're looking for, so you get behind on various aspects of task: was still transitioning to 60 knots when had to start descent.

REASON FOR RATING: Did see 200 ft off altitude at one point in approach. If things don't stray too far off and you don't have to make large correction, it works out pretty good.

SPECIFICS:

TRIM:

PITCH RESPONSE: Same comments as before (out of turbulence).

ROLL RESPONSE: Not really predictable. Is hunt-and-peck system: put some in, take some out until you get what you want.

SPEED CONTROL: Takes too long to make speed change. With this control system, you're too busy making the speed change.

TURN COORDINATION: Kind of hunting to get turn established so it's a workload item. Not using much rudder, willing to sacrifice rudder if can get right roll attitude, ball is not doing much.

THRUST CONTROL: OK.

TASK PERFORMANCE: Most difficulty in early part of task, would get off in altitude or speed, seemed to catch up with things in the descent.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	4½		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 189-191		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Felt like good configuration except for lack of force trim. Stable all axes. Minimal coupling among axes.

OBJECTIONABLE FEATURES: Had to work harder because of lack of force trim. Only really bad feature.

REASON FOR RATING: Between moderate and considerable compensation required.

SPECIFICS:

TRIM:

PITCH RESPONSE: Predictable.

ROLL RESPONSE: Predictable.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	PILOT RATING (IN TURBULENCE)	5½	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.57 in./15°			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS:	189-191	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Same as in no turbulence.

OBJECTIONABLE FEATURES: Constant small corrections required plus lack of force trim.

REASON FOR RATING: Didn't require maximum tolerable pilot compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Made lack of force trim a bigger gripe.

CONFIGURATION ID:	S13	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		PILOT:	M
LATERAL POSITION GRADIENT:	0.57 in./15°	8	FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS: 302-304	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Comments lost.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	8½		**PILOT:**	M
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	302-304	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Limp stick has effect of reducing the apparent stability of the aircraft because pilot cannot for a moment let go of machine. Inputs can become gross, can result in gross departures very rapidly. Found large divergence in pitch if I even glanced at power or sideslip. Force helps because it gives you an input datum. Friction would ensure that too.

REASON FOR RATING: Didn't crash! Some moments when intense pilot compensation was required for control.

SPECIFICS:

TRIM:

PITCH RESPONSE: Lots and lots of inadvertent and required inputs.

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°	4½		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	318-320	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: No need for trimming, lack of transients from trimming. Fairly smooth.

OBJECTIONABLE FEATURES: A sense that you don't have any stability, can't dare turn and look away for even a split second.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Transients came from power changes.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Got preoccupied with power, overshot final altitude again.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S13	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	318-320	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Workload high because you can't leave it alone, have to concentrate and constantly fly attitude.

REASON FOR RATING: Considerable pilot compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Overshot altitude again because of preoccupation with other instruments, but can't fault the configuration too much for it.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S14	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	6		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 19-23		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Glad it has good turn coordination. If had problem with that it would have been tougher.

OBJECTIONABLE FEATURES: Mostly lack of reference positions for cyclic stick.

REASON FOR RATING: Very objectionable, extensive pilot compensation required.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Lack of position speed stability didn't really create any problems. Couldn't tell that it was any worse than the one that had stable position stability without force gradient.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S14	**PILOT RATING (IN TURBULENCE)** 6	**ROTOR:** HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		**PILOT:** H
LATERAL POSITION GRADIENT:	0.57 in./15°		**FORCE FEEL:** OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:** 19-23	**SCAS:** RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Might have had to work a little harder to attain the performance I was able to (than for run without turbulence).

CONFIGURATION ID:	S14	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	G
LATERAL POSITION GRADIENT:	0.57 in./15°	7		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	RUNS:	113-115	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Poor speed control in missed approach.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Degraded. Neutral longitudinal stability noted in free run. Speed got down to 40 knots in missed approach.

TURN COORDINATION: Not a problem.

THRUST CONTROL: Fine. Coupling into yaw noted.

TASK PERFORMANCE: Deceleration affected. VOR tracking and acquisition not affected, OK. Descent, missed approach degraded in terms of speed and rate of climb control, although descent not too bad.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S14	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	7½		**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.72 in./15°	**RUNS:**	113-115	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Performance not much different, workload higher.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Got distracted once not getting power change in in time, looked away from attitude indicator longer than normal, airspeed started to decay fairly rapidly and had to make rapid correction. This is type of thing that can happen with neutral speed stability and no force gradient, kind of tends on dangerous.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Adds more disturbance that maybe some stick force gradient would help pilot with.

CONFIGURATION ID:	S15	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		**PILOT:**	H
LATERAL POSITION GRADIENT:	-0.01 in./15°	5½	**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:** 27-29	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Seemed stable in all axes, although a little hard to determine without a trim reference. Not a whole lot of control cross-coupling noticeable.

OBJECTIONABLE FEATURES: Lack of trim reference.

REASON FOR RATING: Moderately objectionable deficiencies are lack of trim reference.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S15	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	6		PILOT:	H
LATERAL POSITION GRADIENT:	-0.01 in./15°			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	27-29	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turbulence bothered me less than previous run.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: More of a contrast with no-turbulence run than previous runs I've seen (S01, S02, S13, S14, S03). May just be me getting tired or it might have been the difficulty of the configuration.

CONFIGURATION ID: S15	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: -0.01 in./15°	6½	**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT: -0.71 in./15°	**RUNS:** 116-118	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Note: Pilot apparently thought configuration would have poor directional stability, and comments will indicate so.

OBJECTIONABLE FEATURES:

REASON FOR RATING: High workload associated with trying to hold attitudes.

SPECIFICS:

TRIM:

PITCH RESPONSE: The same (good).

ROLL RESPONSE: The same (good).

SPEED CONTROL: Pretty good. Had static stability.

TURN COORDINATION: Surprisingly little difficulty with yaw axis. Didn't see any effects of sideslip being induced. Expected problem, didn't see any.

THRUST CONTROL: OK, coupling into yaw not a major problem as was expected.

TASK PERFORMANCE: VOR tracking halfway descent. Deceleration OK. Some overshoot on VOR acquisition. Descent and levelling-off all right. Missed approach surprisingly steady. Expected to see unsteady turn rate, but it was no problem.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S15	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	7		PILOT:	G
LATERAL POSITION GRADIENT:	-0.01 in./15°			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	116-118	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Almost unbelievable that the thing flies as well as it does with the type of directional stability that I thought I saw in the free run.

OBJECTIONABLE FEATURES:

REASON FOR RATING: No worse performance than in clear air.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Affected slightly because of disturbance in pitch axis due to turbulence.

TURN COORDINATION: No particular problem.

THRUST CONTROL:

TASK PERFORMANCE: Very little change.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S16	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	G
LATERAL POSITION GRADIENT:	-0.01 in./15°	7		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS: 64-66		SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Did better than thought I would after free run.

OBJECTIONABLE FEATURES: Pilot workload high. Didn't like having to hold limp stick.

REASON FOR RATING: Want it to be below line.

SPECIFICS:

TRIM:

PITCH RESPONSE: Can't stop attitude precisely with no force-feel system, get overshoot, not a big problem IFR.

ROLL RESPONSE: Same as roll.

SPEED CONTROL: Terrible but not as bad as I'd thought it would be. Required concentrated scan of pitch attitude.

TURN COORDINATION: Not a specific problem.

THRUST CONTROL: No worse than any other runs I've seen.

TASK PERFORMANCE: VOR tracking pretty good, tried pretty hard. Got established in descent nicely. Transitions not so good. Missed approach surprisingly good considering lack of trim and poor longitudinal statics.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S16	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	8		PILOT:	G
LATERAL POSITION GRADIENT:	-0.01 in./15°			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	64-66	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: One good thing about no force-feel is that you don't try to retrim, which is actually advantage with poor control situation. Kind of a trade-off.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: VOR tracking surprisingly good. Speed control lousy, transitions took a long time to stabilize onto level, climb, or descent. Turn rate during missed approach moving all over the place.

EFFECTS OF TURBULENCE: All over — pitch, roll, sideslip excursions. Higher workload, degraded performance.

CONFIGURATION ID:	S16	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	-0.01 in./15°	5½		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:** 98-100		**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turn coordination, didn't have to work hard with pedals. No problems with predictability of control response.

OBJECTIONABLE FEATURES: Lack cf force gradient, lack of trim reference.

REASON FOR RATING: Had to constantly fly it, but performance pretty good.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Neutral longitudinal static stability was not noticeable IFR.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S16	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5½		PILOT:	H
LATERAL POSITION GRADIENT:	-0.01 in./15°			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS:	98-100	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Lack of trim reference more objectionable in turbulence.

REASON FOR RATING: Could have been worse and I could still have gotten adequate performance, although not a lot worse.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S16	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	-0.01 in./15°	5		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	RUNS 254-256		SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Still have workload on keeping speed, keeping nose attitude very tight. Ratchet effects on turns, can't get balanced turn.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Nose attitude got away at level-off after missed approach — you can't look away very long before you're wandering off somewhere.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S16	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5		**PILOT:**	K
LATERAL POSITION GRADIENT:	-0.01 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.71 in./15°	**RUNS:**	254-256	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: No changes.

CONFIGURATION ID:	S17	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°	6	**FORC. FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:** 51-53	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Had to make corrections entire time to hold desired attitude or bank angle, wasn't doing very well at it some times. Worst feature is lack of trim reference.

REASON FOR RATING: Very objectionable deficiencies, required extensive pilot compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S17	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	6		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	51-53	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Adequate performance attainable — didn't do quite so good at one point but think that was poor pilot technique.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Not much worse in turbulence. At one point had more problem with airspeed control but it was because I was going to sleep at stick and looking at something else.

CONFIGURATION ID:	S17	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°	6½		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	119-121	**SCAS:**	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Speed control, weak directional stability either fed into speed control or had to spend more time contending with lateral-directional.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Poor.

TURN COORDINATION: A problem, mostly by what I felt and not what I saw.

THRUST CONTROL: Transients caused uncomfortable, unbalanced flight condition.

TASK PERFORMANCE: VOR tracking degraded — had good control of attitude correction for heading, but heading doesn't mean much if aircraft is slipping. Deceleration OK. VOR acquisition not too good — was to right of station. Missed approach the same.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S17	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		8	**PILOT:**	G
LATERAL POSITION GRADIENT:	0.57 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	**RUNS:**	119-121	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Lots of roll disturbance coming in. Trying to correct for roll caused over-control in pitch.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: All worse.

EFFECTS OF TURBULENCE: Sideslip excursions upsetting roll.

CONFIGURATION ID: S17	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: 0.57 in./15°	5	FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT: -0.19 in./15°	RUNS: 229-231	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: No coupling at all. Fairly pleasant to fly.

OBJECTIONABLE FEATURES: Limp noodle stick, any tendency to introduce motion to stick is transmitted right away into flightpath and attitude. Workload is to keep hand still until ready to move it.

REASON FOR RATING:

SPECIFICS:

TRIM: Not used.

PITCH RESPONSE: Immediate responses, no lags.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL: Response to attitude change looked normal. Control was good.

TURN COORDINATION: Good, could get into steady turn.

THRUST CONTROL: Fine. Did not upset anything when I made power changes.

TASK PERFORMANCE: Everything good, no serious glitches. Have to rest forearm on leg to steady hand.

EFFECTS OF TURBULENCE:

AD-A093 654 NATIONAL AERONUATICS AND SPACE ADMINISTRATION MOFFET--ETC F/G 1/2
A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABI--ETC(U)
SEP 80 J V LEBACQZ, R D FORREST, R M GERDES
UNCLASSIFIED NASA-A-8125 NASA-TM-81188 NL

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CONFIGURATION ID:	S17	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots		$5\frac{1}{2}$	PILOT:	K
LATERAL POSITION GRADIENT:	0.57 in./15			FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.19 in./15°	RUNS:	229-331	SCAS:	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Workload was heavier throughout, more on top of things as a result of turbulence. All features were same as in no turbulence.

CONFIGURATION ID:	S18	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	G
LATERAL POSITION GRADIENT:	0.03 in./15°	7		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	80-83	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: A lot of pilot workload trying to hold right attitude and contend with sideslip. Didn't like having no friction. Task very demanding – jerky ride caused by me trying to put in corrective inputs.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Satisfactory, but lack of friction or centering detracts.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL: Not too bad, but not so good.

TURN COORDINATION: Poor.

THRUST CONTROL: Sizeable yaw couple input from power changes. Probably would have done worse without sideslip indicator. If just keep ball centered it deceives you because you can be flying along in sideslip and not tracking radial. Need directional stability for this task.

TASK PERFORMANCE: Deceleration not so good – gained altitude due to overcontrol in pitch. VOR tracking poor. Transitions were aggravated by yaw due to collective. Missed approach same problem, speed control not good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S18	**PILOT RATING (IN TURBULENCE)**	8	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.03 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	80-83	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Almost academic. Now I am inducing a lot of disturbances to flightpath and aircraft attitude and turbulence is too, causing even more problems.

REASON FOR RATING:

SPECIFICS:

TRIM: Don't know if friction would help or not, airplane is so bad directionally.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Everything deteriorated.

CONFIGURATION ID: S18	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.64 in./20 knots		PILOT:	H
LATERAL POSITION GRADIENT: 0.03 in./15°	5	FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT: -0.18 in./15°	RUNS: 131-133	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Seemed that it would have been pretty nice if I'd had a force trim.

OBJECTIONABLE FEATURES: No reference position to trim.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Pretty nice.

ROLL RESPONSE: Pretty nice.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S18	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.03 in./15°	$5\frac{1}{2}$		**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	131-133	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Could have gotten adequate performance with worse configuration. More than considerable pilot compensation, however.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S18	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.03 in./15°	5		FORCE FEEL:	OFF
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	RUNS:	263-265	SCAS:	RATE

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Kind of liked flying limp noodle, lack of force seemed sort of pleasant. Speed control pretty good except during transitions.

OBJECTIONABLE FEATURES:

REASON FOR RATING: Configurations getting hard to rate, running together. Tend to try always to make each correction as small as possible, never get any big excursions, hard to see the shades between them.

SPECIFICS:

TRIM: Didn't miss it.

PITCH RESPONSE: Very responsive. Fairly predictable.

ROLL RESPONSE: Very responsive.

SPEED CONTROL: Fairly predictable — see you're off, make small correction.

TURN COORDINATION: All my turns seem sloppy for all configurations. This one seems a little smoother if I take it real slow.

THRUST CONTROL:

TASK PERFORMANCE: Got off about 10 knots at end of missed approach. Have to rest forearm on knee as fulcrum.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S18	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.64 in./20 knots	5½		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.03 in./15°			**FORCE FEEL:**	OFF
DIRECTIONAL POSITION GRADIENT:	-0.18 in./15°	**RUNS:**	263-265	**SCAS:**	RATE

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Speed control poor, turn control not good although better than some other configurations.

REASON FOR RATING:

SPECIFICS:

TRIM: Not used.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Good and predictable except when making transitions.

TURN COORDINATION: Felt better than some others. Put it in gently and not get ratchet.

THRUST CONTROL:

TASK PERFORMANCE: Good except for go-around, it got pretty ragged.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S21	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	5	**PILOT:** H	
LATERAL POSITION GRADIENT: 0.00 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 48-50	**SCAS:** TDA	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Turn coordination.

OBJECTIONABLE FEATURES: Didn't seem to be statically stable — neutral, although wasn't as bad IMC as I'd thought it would be.

REASON FOR RATING: Considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S21	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		5½	**PILOT:**	H
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	48-50	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Workload higher, performance not as good.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Not as precise in turbulence.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S21	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.00 in./15°	5	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 84-86	**SCAS:**	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Lateral-directional pretty good, except for some yaw due to collective which I noticed because of having to put in some unplanned inputs.

OBJECTIONABLE FEATURES: Speed control.

REASON FOR RATING: Marked down for longitudinal problems.

SPECIFICS:

TRIM: Was able to trim throughout approach, used beeper.

PITCH RESPONSE: Good. Had to make some steep pitch changes to correct for velocity errors and it looked OK.

ROLL RESPONSE: Good.

SPEED CONTROL: Problem. I think because of lack of attitude loop. High workload maintaining pitch attitude.

TURN COORDINATION: OK, some tendency to right sideslip at slower speeds.

THRUST CONTROL:

TASK PERFORMANCE: Deceleration OK, some altitude change. VOR acquisition and tracking looked good. Had some directional divergences flying collective in transitions, but not real bad. Speed control was problem in missed approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S21	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots	7	**PILOT:**	G
LATERAL POSITION GRADIENT: 0.00 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 84-86	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: High workload, poor performance in turbulence.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE: Some roll disturbances, had trouble with bank attitude.

SPEED CONTROL: Worse in turbulence.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Had unsteady turn rate in missed approach, deteriorated.

EFFECTS OF TURBULENCE: Additionally degraded pitch and speed control as well as turn and turning performance in missed approach.

CONFIGURATION ID: S21	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: 0.00 in./15°	4	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 226-228	SCAS:	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Had problem with turn control.

REASON FOR RATING:

SPECIFICS:

TRIM: OK.

PITCH RESPONSE: Crisp, light response, OK.

ROLL RESPONSE: OK. Tend to roll further into turn than I mean to. Maybe I'm not using rudder as much as I should.

SPEED CONTROL: Relatively good, got off a few times.

TURN COORDINATION: Requires work for me.

THRUST CONTROL: Adequate.

TASK PERFORMANCE: Nothing to elaborate on.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S21	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots	5		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	226-228	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Roll control and turbulence. More work on roll required, consequently fell over into pitch, started working harder on airspeed control.

REASON FOR RATING: Considerable compensation required.

SPECIFICS:

TRIM: OK. Coupling noticed when power added for climbout, retrim.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL: Coupling definitely noticed. Had to make definite attitude change when power added for climbout, speed fell off. Same thing happened at end of climbout.

TASK PERFORMANCE: Got off to bad start on this one and previous one, not sure why. Something catches my attention, overshot radial, had to make radical turn to catch radial back. Also wandered off on altitude more than I would approve of.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S21	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.01 in./20 knots		**PILOT:** M	
LATERAL POSITION GRADIENT: 0.00 in./15°	3½	**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 371-373	**SCAS:** TDA	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Directional stability helped a lot.

OBJECTIONABLE FEATURES: Some airspeed looseness, had to change airspeed quite a lot. Still had slip angle, had to pay more attention to yaw than I like.

REASON FOR RATING: Airspeed chasing mildly unpleasant, slip angle minor but annoying, will go half way between.

SPECIFICS:

TRIM: Nice on pitch/roll, beeper used. Didn't trim directional.

PITCH RESPONSE: A little sluggish.

ROLL RESPONSE: Quite good.

SPEED CONTROL: Require more changes than I like.

TURN COORDINATION: Very good in turn, some slip on entry and exit of turns, felt like N_{δ_A} on fixed wing.

THRUST CONTROL:

TASK PERFORMANCE: Pretty fair. Tracking, descent OK. Airspeed control in missed approach loose.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S21	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.01 in./20 knots		3½	**PILOT:**	M
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	371-373	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: No worse than still air. Workload wasn't minimal but wasn't moderate either.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Didn't seem to have much effect. Perhaps yaw augmentation sufficiently relieved me in that axis so I could concentrate on others.

CONFIGURATION ID: S24	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots	3	PILOT:	G
LATERAL POSITION GRADIENT: 0.54 in./15°		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 77-79	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Could trim it up in missed approach.

OBJECTIONABLE FEATURES: A little right sideslip tendency.

REASON FOR RATING: Some compensation required for minor coupling due to power into pitch.

SPECIFICS:

TRIM: Excellent. Used both trim systems.

PITCH RESPONSE: Good, no overcontrol tendencies.

ROLL RESPONSE: Good.

SPEED CONTROL: Good.

TURN COORDINATION: Excellent.

THRUST CONTROL: Good.

TASK PERFORMANCE: Very little altitude loss during deceleration is good indicator of how well you can do. All looked good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S24	PILOT RATING (IN TURBULENCE) 3	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots		PILOT:	G
LATERAL POSITION GRADIENT: 0.54 in./15°		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 77-79	SCAS:	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Best IMC run in turbulence I've made.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Not much additional compensation required.

CONFIGURATION ID: S24	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots		PILOT:	H
LATERAL POSITION GRADIENT: 0.54 in./15°	3	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 128-130	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Like just about everything.

OBJECTIONABLE FEATURES: Would like heading hold.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Trimmed out steady force laterally in missed approach, seemed to make it easier.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots	3		PILOT:	H
LATERAL POSITION GRADIENT:	0.54 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	128-130	SCAS:	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Prefer rate-command-attitude-hold slightly.

REASON FOR RATING: Performance maybe not as good, but I didn't work any harder.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Not much effect.

CONFIGURATION ID: S24	PILOT RATING (NO TURBULENCE)	ROTOR: HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots	2½	PILOT: G
LATERAL POSITION GRADIENT: 0.54 in./15°		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 219-221	SCAS: AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Almost everything. All tracking good.

OBJECTIONABLE FEATURES: Some pitch attitude change required to maintain speed with power variations.

REASON FOR RATING: A little compensation changing attitude to maintain speed.

SPECIFICS:

TRIM: Good. Used both systems.

PITCH RESPONSE: All good.

ROLL RESPONSE: All good.

SPEED CONTROL: Some monitoring to make precise pitch changes as power varied. If not anticipated, will speed up when power added.

TURN COORDINATION: Good.

THRUST CONTROL: Good. Maybe a little coupling to pitch.

TASK PERFORMANCE: Good. Only some small deviations in desired speed.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	**PILOT RATING (IN TURBULENCE)**	3	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	0.54 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	219-221	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Pretty much the same.

OBJECTIONABLE FEATURES: Some deviation in speed control.

REASON FOR RATING: A little more compensation changing attitude to maintain speed, concentrating on pitch.

SPECIFICS:

TRIM:

PITCH RESPONSE: All good. Couldn't see significant differences between hingeless and teetering with this control system.

ROLL RESPONSE: Good.

SPEED CONTROL: Some deterioration. Definite requirement to change pitch to maintain speed when power is changed.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Seen in pitch axis, required increased precision.

CONFIGURATION ID:	S24	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.54 in./15°	3		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	266-268	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: All good.

OBJECTIONABLE FEATURES:

REASON FOR RATING: Minimal compensation required for desired performance.

SPECIFICS:

TRIM: Used beeper trim, had plenty of time to trim.

PITCH RESPONSE: Easy to attain.

ROLL RESPONSE: Good.

SPEED CONTROL: Good.

TURN COORDINATION: Good — would just roll in using beeper trim, made nicely coordinated turn.

THRUST CONTROL: Good.

TASK PERFORMANCE: Good throughout. Mild deviations toward the very very end.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	PILOT RATING (IN TURBULENCE)	4	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.54 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	266-268	SCAS:	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: More control inputs required.

REASON FOR RATING: More difficult, performance worse in turbulence.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Not as good as out of turbulence.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S24	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots	3	**PILOT:** H	
LATERAL POSITION GRADIENT: 0.54 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 330-332	**SCAS:** AC	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Favorite airplane. Didn't take as much control throw as previous one (S27), liked better even though rating same. Predictable, held attitude without any great effort on my part.

OBJECTIONABLE FEATURES: None really. Prefer rate command attitude retention. Would like heading hold for straight portion of task.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	**PILOT RATING (IN TURBULENCE)**	3	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.54 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	330-332	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Had to work a little at it.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Had to work a little harder with pedals to hold trim.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S24	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: -0.15 in./20 knots		PILOT:	M
LATERAL POSITION GRADIENT: 0.54 in./15°	2	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 354-356	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Delightful to fly, undemanding.

OBJECTIONABLE FEATURES: Do not like attitude command systems in lateral axis, don't like holding force in turn. Got larger slip angles feet off in turns than would have liked, although flying yaw was easy.

REASON FOR RATING: Lateral attitude command not highly desirable, but pilot compensation not a factor.

SPECIFICS:

TRIM: Excellent. Beeper used.

PITCH RESPONSE: Crisp, predictable, clean, no coupling.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL: Delightful, no problem.

TURN COORDINATION: No problem.

THRUST CONTROL:

TASK PERFORMANCE: Quite adequate.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots	2		**PILOT:**	M
LATERAL POSITION GRADIENT:	0.54 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	354-356	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Same as out of turbulence.

OBJECTIONABLE FEATURES: Would like crisper response going back to wings level.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: See sideslip and airspeed meters move, but not attitude. Didn't fundamentally change the handling problem or the accuracy of the task.

CONFIGURATION ID	S24	PILOT RATING (IN TURBULENCE)	ROTOR: HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots	3	PILOT: K
LATERAL POSITION GRADIENT:	0.54 in./15°		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS: 364-367	SCAS: AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: All features good.

OBJECTIONABLE FEATURES: Trying to get correct nose attitude for the go-around maneuver to maintain 60 knots.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S24	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	-0.15 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.54 in./15°	3½		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	364-367	SCAS:	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Good all around.

OBJECTIONABLE FEATURES: Requires different nose attitude for left-hand as opposed to right-hand turns. This one was right hand, requires more nose up.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S25	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		**PILOT:**	H
LATERAL POSITION GRADIENT: 0.00 in./15°	3	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 57-59	**SCAS:**	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: I like! Wouldn't hesitate to fly IFR. Everything good.

OBJECTIONABLE FEATURES: Slight collective to lateral-longitudinal coupling, so small wouldn't have noticed it if didn't have attitude system.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: No real influence.

CONFIGURATION ID:	S25	PILOT RATING (NO TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.00 in./15°	$2\frac{1}{2}$		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	57-59	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Had to work a little once in awhile. It was so good I just relaxed too much and performance wasn't as good as it should have been.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S25	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.00 in./15°	2½	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 149-151	**SCAS:**	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Hands off controls during all segments of approach. Attitude stability.

OBJECTIONABLE FEATURES: Some requirement for pedals to keep ball centered.

REASON FOR RATING:

SPECIFICS:

TRIM: Outstanding. Used trim release to change from 80 to 60 knots, didn't retrim after that. Trimmed pedals with beeper in climb.

PITCH RESPONSE: Good. Did not miss the fact that there's no apparent static stability — neutral.

ROLL RESPONSE:

SPEED CONTROL: Outstanding.

TURN COORDINATION: Not perfect.

THRUST CONTROL: A little coupling to directional axis.

TASK PERFORMANCE: Hands off missed approach climb! All aspects good.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S25	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots	3	**PILOT:**	G
LATERAL POSITION GRADIENT: 0.00 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 149-151	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Hands off again for portions of that. Attitude hold really masked a lot of the motions. Workload level really lower, am much more relaxed after these two runs.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Slightly degraded but didn't concern me.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S25	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: 0.00 in./15°	3	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 183-185	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Everything.

OBJECTIONABLE FEATURES: Didn't see anything.

REASON FOR RATING: Ability to fly whole approach with beeper trim.

SPECIFICS:

TRIM: Excellent. Used beeper longitudinally and laterally, no directional trim used.

PITCH RESPONSE: Fine. Fairly predictable.

ROLL RESPONSE:

SPEED CONTROL: Have to know in turn you're going to need a new pitch attitude. Very good control because of being able to make minor attitude changes with beeper trim.

TURN COORDINATION: No problems, even in missed approach.

THRUST CONTROL:

TASK PERFORMANCE: Sure acceptable to me.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S25	PILOT RATING (IN TURBULENCE)		ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots		3½	PILOT:	K
LATERAL POSITION GRADIENT:	0.00 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	RUNS:	183-185	SCAS:	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Some problem, when got below 60 knots, getting it back on 60, response to correction seemed slow.

REASON FOR RATING: Worked a little harder.

SPECIFICS:

TRIM: Mostly used beeper, once or twice the mag brake.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Got off.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Performance wasn't as good — overshot altitude on missed approach — but these things were because the configuration was so good I got lazy.

EFFECTS OF TURBULENCE: Required more inputs to be made, but certainly not very objectionable.

CONFIGURATION ID: S25	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		**PILOT:**	H
LATERAL POSITION GRADIENT: 0.00 in./15°	3	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 195-197	**SCAS:**	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Predictable responses, attitude hold.

OBJECTIONABLE FEATURES: Would like heading hold and possibly airspeed hold or altitude hold.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S25	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots	3		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	195-197	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Same.

OBJECTIONABLE FEATURES: Same.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Turbulence didn't make much difference — may have cut down performance accuracy somewhat, but think performance limited more by my cross-check and ability to respond than by configuration flying qualities.

CONFIGURATION ID: S25	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** HINGELESS	
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots	3	**PILOT:** M	
LATERAL POSITION GRADIENT: 0.00 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	**RUNS:** 305-307	**SCAS:** RCAH	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Can let the thing go and it'll go the way it's pointing.

OBJECTIONABLE FEATURES: Some roll to pitch coupling, comes through attitude hold system: pitch change required in climbing turns.

REASON FOR RATING: Some pilot compensation required.

SPECIFICS:

TRIM: Good all three axes. Beeper used. Button beeper for yaw used in sustained turn.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: Good, did drift off but that was my fault for not compensating adequately for roll to pitch couple.

TURN COORDINATION: Good.

THRUST CONTROL:

TASK PERFORMANCE: All good. Missed approach no problem except for roll-pitch couple.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S25	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			**PILOT:**	M
LATERAL POSITION GRADIENT:	0.00 in./15°	3½		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	305-307	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Can let it go hands-off and it keeps going in the right direction.

OBJECTIONABLE FEATURES: Problem with airspeed. Pitch coupling and collective to yaw coupling.

REASON FOR RATING: It's not bad enough for a 4.

SPECIFICS:

TRIM: Good.

PITCH RESPONSE: No problems.

ROLL RESPONSE: No problems.

SPEED CONTROL: Pitch to speed relationship good. Think I got lazy or tired and got large airspeed excursion during missed approach.

TURN COORDINATION: No problem.

THRUST CONTROL: No problem.

TASK PERFORMANCE: Good except for speed control.

EFFECTS OF TURBULENCE: Noticed in airspeed variation. Sideslip variation causing a little bit of coupling.

CONFIGURATION ID: S25	PILOT RATING (NO TURBULENCE)	ROTOR:	HINGELESS
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: 0.00 in./15°	3	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.09 in./15°	RUNS: 360-363	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Didn't see any.

REASON FOR RATING:

SPECIFICS:

TRIM: Just occasionally used mag brake.

PITCH RESPONSE: Acceptable.

ROLL RESPONSE: Acceptable.

SPEED CONTROL: Very good and predictable.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Used wrong power setting on go-around, overshot altitude as result. Otherwise a good approach.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S25	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	HINGELESS
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots		$4\frac{1}{2}$	**PILOT:**	K
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.09 in./15°	**RUNS:**	360-363	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Definite increase in workload, saw too much variance in speed.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Didn't expect it to have this much effect. Had rhythmic increasing and decreasing in roll during go-around.

CONFIGURATION ID:	S26	**PILOT RATING (NO TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.03 in./20 knots			**PILOT:**	G
LATERAL POSITION GRADIENT:	-0.05 in./15°	$4\frac{1}{2}$		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.9 in./15°	**RUNS:**	213-215	**SCAS:**	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Directional axis improvement, no problems with effects of sideslip excursions.

OBJECTIONABLE FEATURES: Speed control problem.

REASON FOR RATING: Speed control. Change in directional (from S10 evaluated previously) gets airplane to acceptable but is below $3\frac{1}{2}$ because of longitudinal characteristics.

SPECIFICS:

TRIM: Good. Used mag brake.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: Some divergent tendency. Because of good directional can concentrate more on speed. Some overcontrol getting speed back on.

TURN COORDINATION: OK. Turn rates and heading control all right.

THRUST CONTROL: Shouldn't be dropping collective as abruptly at end. Some coupling in pitch, not as apparent as coupling to yaw.

TASK PERFORMANCE: Lost speed at top of missed approach, but no large sideslip.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S26	PILOT RATING (IN TURBULENCE)	7	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.03 in./20 knots			PILOT:	G
LATERAL POSITION GRADIENT:	-0.05 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	213-215	SCAS:	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: High workload, aircraft suitability very sensitive to change in directional characteristics caused by turbulence.

SPECIFICS:

TRIM: OK.

PITCH RESPONSE: Same.

ROLL RESPONSE: Same.

SPEED CONTROL: Degraded because of pitch disturbances.

TURN COORDINATION: Degraded both on entering and holding turn, sideslip problems coming in.

THRUST CONTROL: Same.

TASK PERFORMANCE: Degraded for tracking, descent control, speed control, and missed approach. At very top, did not lose airspeed because this time I pitched over.

EFFECTS OF TURBULENCE: Small degradation in speed control. Made some lateral-directional problems appear in the way of sideslip excursions.

CONFIGURATION ID: S26	PILOT RATING (NO TURBULENCE)	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.03 in./20 knots	4	PILOT:	H
LATERAL POSITION GRADIENT: -0.05 in./15°		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	RUNS: 321-323	SCAS:	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Responses predictable, pretty well decoupled.

OBJECTIONABLE FEATURES: Constant small corrections to hold attitude or bank angle.

REASON FOR RATING: Moderate compensation.

SPECIFICS:

TRIM: No problem.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: It appeared to have neutral longitudinal and lateral stability during VFR run, but did not create apparent problem IFR.

TURN COORDINATION: No problem at all.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S26	PILOT RATING (IN TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.03 in./20 knots		5	PILOT:	H
LATERAL POSITION GRADIENT:	-0.05 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	321-323	SCAS:	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Predictable control responses.

OBJECTIONABLE FEATURES: Had trouble with heading in turbulence.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Rougher, but part of that was due to the fact that I was devoting more attention to heading hold.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S26	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.03 in./20 knots	5	**PILOT:**	K
LATERAL POSITION GRADIENT: -0.05 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 342-344	**SCAS:**	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Don't have to use mag brake, just hold against the force, could do whole job in very tiny circle (of control motion).

OBJECTIONABLE FEATURES: Speed response to attitude change not predictable.

REASON FOR RATING: Fairly large speed excursions, went from 70 down to nearly 50.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S26	PILOT RATING (IN TURBULENCE)	5½	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.03 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	-0.05 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	342-344	SCAS:	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Commentary the same. Speed control the most difficult.

REASON FOR RATING: Speed problem is the one that puts it down pretty well.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Had trouble with tracking in the beginning.

EFFECTS OF TURBULENCE: Worked on me laterally I think.

CONFIGURATION ID: S27	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** TEETERING	
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots	$2\frac{1}{2}$	**PILOT:** G	
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 216-218	**SCAS:** AC	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Very low workload task. Everything good.

OBJECTIONABLE FEATURES: Requirement to change attitude with power setting to maintain speed.

REASON FOR RATING:

SPECIFICS:

TRIM: Excellent. Used mag brake as easier.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: Good. Had to compensate attitude for new power setting.

TURN COORDINATION:

THRUST CONTROL: Excellent, coupling hardly noticeable.

TASK PERFORMANCE: Good all the way through.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S27	**PILOT RATING (IN TURBULENCE)** 3	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 216-218	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Attitude system isolated turbulence disturbances.

OBJECTIONABLE FEATURES: Same: need to change attitude with power to maintain speed.

REASON FOR RATING: Slight increase in workload.

SPECIFICS:

TRIM: Same.

PITCH RESPONSE: Same.

ROLL RESPONSE: Same.

SPEED CONTROL: A little disturbance in pitch from turbulence.

TURN COORDINATION: Same.

THRUST CONTROL: Same.

TASK PERFORMANCE: Same.

EFFECTS OF TURBULENCE: Very little influence on pitch.

CONFIGURATION ID: S27	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots	3	**PILOT:**	H
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 327-329	**SCAS:**	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Like attitude command, although like rate command attitude retention better.

OBJECTIONABLE FEATURES: Required fairly large control throws for attitude changes.

REASON FOR RATING: Minimal compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE: Would have liked to get given bank angle without having to move the control so far.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S27	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots	3½	**PILOT:**	H
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 327-329	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Didn't like large control throws to change an attitude. Would have called it a 3 if had half the control throws.

REASON FOR RATING: Would like to see a little improvement in configuration, but it isn't moderate compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S27	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT: 0.95 in./15°	3	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 368-370	**SCAS:**	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: All good, no complaints.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: So well behaved didn't bother trimming, just hold force.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Excellent, very predictable even in turns.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S27	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	-0.18 in./20 knots		4	**PILOT:**	K
LATERAL POSITION GRADIENT:	0.95 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	**RUNS:**	368-370	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Other than speed, pretty good.

OBJECTIONABLE FEATURES:

REASON FOR RATING: Turbulence made speed control quite a bit more difficult.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Couldn't predict it well, had to make repeated attitude adjustments to bring it back to 60 knots.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S27	**PILOT RATING (NO TURBULENCE)**	**ROTOR:** TEETERING	
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots	2	**PILOT:** M	
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:** ON	
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 380-382	**SCAS:** AC	

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Like largish control throws required, gives improved resolution. Pitch channel very good.

OBJECTIONABLE FEATURES: Would prefer faster return to wings level. Would prefer rate-command-attitude-hold laterally, don't like holding force in turns.

REASON FOR RATING: Compensation not a factor for desired performance.

SPECIFICS:

TRIM: Excellent, didn't have to retrim at all.

PITCH RESPONSE: Absolutely beautiful, trim rate well matched.

ROLL RESPONSE: Liked larger stick deflections.

SPEED CONTROL: Super.

TURN COORDINATION: Nothing was a problem.

THRUST CONTROL:

TASK PERFORMANCE: Not a problem.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S27	**PILOT RATING (IN TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: -0.18 in./20 knots	2	**PILOT:**	M
LATERAL POSITION GRADIENT: 0.95 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 380-382	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Same.

OBJECTIONABLE FEATURES: Still would like rate command laterally.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Sloppy, but I think it something lacking in me, I was looking at other things too much. Desired airspeed performance not met, but my fault.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Only observed influence on airspeed and sideslip meters.

CONFIGURATION ID: S28	PILOT RATING (NO TURBULENCE)	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots	4	PILOT:	C
LATERAL POSITION GRADIENT: 0.00 in./15°		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	RUNS: 67-70	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Attitude hold reduces workload significantly, particularly in lateral task. Turn coordination, lateral-directional control system really good.

OBJECTIONABLE FEATURES: Some jerkiness, little lateral PIO, have to be ginger with lateral inputs. Speed control surprisingly bad. Although pitch control is good, aircraft required different pitch attitude for same speed when power is changed. (Lateral sensitivity reduced for subsequent evaluations.)

REASON FOR RATING: Problem with speed control.

SPECIFICS:

TRIM: Excellent all around.

PITCH RESPONSE: Harsh, abrupt although nice and solid.

ROLL RESPONSE: Same, a little too snappy, could induce PIO.

SPEED CONTROL: Good once power is set, but have to change attitude with power to maintain speed.

TURN COORDINATION: Excellent.

THRUST CONTROL: Excellent.

TASK PERFORMANCE: Some problem with speed control during deceleration because of pitch reponse and need for attitude change with power. VOR tracking looked fine, reflects excellent lateral-directional dynamics.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S28	PILOT RATING (IN TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots		4	PILOT:	G
LATERAL POSITION GRADIENT:	0.00 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	67-70	SCAS:	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Comments lost because of tape recording malfunction.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S23	PILOT RATING (NO TURBULENCE)		ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.00 in./15°	3		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	101-103	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Liked everything.

OBJECTIONABLE FEATURES: Would have liked help holding heading in straight portion of task.

REASON FOR RATING: Would have like a heading hold feature.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Good — no problem seen.

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S28	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots	3½		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	**RUNS:**	101-103	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Everything except lack of heading hold.

OBJECTIONABLE FEATURES: Had to work harder to hold heading, had to make small lateral corrections.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Wandering in heading.

CONFIGURATION ID: S28	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	TEETERING
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		**PILOT:**	K
LATERAL POSITION GRADIENT: 0.00 in./15°	3	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -1.94 in./15°	**RUNS:** 272-274	**SCAS:**	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: Could use beeper throughout turns. Never used rudder trim.

PITCH RESPONSE: Normal, well-behaved.

ROLL RESPONSE: Same as pitch.

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL: Very minimum coupling.

TASK PERFORMANCE: Normal. You get lazy with good configuration, had some speed gyrations I was a little slow to correct, airplane so well behaved I wasn't in any big rush.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S28	PILOT RATING (IN TURBULENCE)	4	ROTOR:	TEETERING
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.00 in./15°			FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-1.94 in./15°	RUNS:	272-274	SCAS:	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Attitude hold.

OBJECTIONABLE FEATURES: Speed and tracking errors I didn't expect.

REASON FOR RATING:

SPECIFICS:

TRIM: Had enough time to use beeper.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Good, but turbulence put more workload into it.

THRUST CONTROL: No coupling seen.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Upped workload.

CONFIGURATION ID:	S29	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots	5½		**PILOT:**	H
LATERAL POSITION GRADIENT:	0.17 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	240-243	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Toying between considerable and extensive compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Had to hold 5-10° nose low attitude to maintain airspeed in missed approach to left; isn't realistic, is simulation deficiency.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S29	PILOT RATING (NO TURBULENCE)		ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.17 in./15°	5		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	RUNS:	240-243	SCAS:	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Initial responses predictable.

OBJECTIONABLE FEATURES: Long turn response left something to be desired. A good deal of cross-coupling noticeable a few seconds after input went in.

REASON FOR RATING: Considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION: Seem to be reading 20-30° of sideslip for ball centered. Doesn't seem realistic. Is like built-in crosswind.

THRUST CONTROL: Considerable coupling to pitch and yaw.

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S29	PILOT RATING (NO TURBULENCE)		ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.17 in./15°	$4\frac{1}{2}$		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	RUNS:	333-335	SCAS:	TDA

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: No coupling.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE: Some learning problem with new rotor type in pitch attitude. Response rapid enough.

ROLL RESPONSE: Roll rapid, not as much overcontrol as I've seen previously (S01-S08).

SPEED CONTROL: Prediction on speeds takes learning, got above 10 knot spread.

TURN COORDINATION: Turns seem to be improving over some of the previous configurations.

THRUST CONTROL: OK, some learning in new power settings required.

TASK PERFORMANCE: Acceptable, no special comments.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S29	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots		5½	**PILOT:**	K
LATERAL POSITION GRADIENT:	0.17 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	333-335	**SCAS:**	TDA

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM: Used mag trim much more than out of turbulence. Actually holding it down so I don't have to feel I'm resetting, just continuously maneuvering. Also had creep in heading, couldn't hold on to good, steady heading.

PITCH RESPONSE: Minor problems.

ROLL RESPONSE:

SPEED CONTROL: Not red hot, had trouble holding pitch attitude.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: Acceptable. Special control technique was flying forces-off for a considerable portion of the time.

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S30	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT: -0.26 in./20 knots		**PILOT:**	G
LATERAL POSITION GRADIENT: 0.50 in./15°	3½	**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.86 in./15°	**RUNS:** 206-208	**SCAS:**	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Attitude stability reduced workload immensely.

OBJECTIONABLE FEATURES: Some pitching and yawing due to collective. Tendency for aircraft to sideslip — weak directionally.

REASON FOR RATING: Fair, enough compensation required to get it below two level.

SPECIFICS:

TRIM: Good pitch and roll. Beeper rate too high directionally for this directional system.

PITCH RESPONSE: Good.

ROLL RESPONSE: Good.

SPEED CONTROL: Good. However, aircraft requires different pitch attitude to hold speed for different power settings. Also have pitching due to collective, which is in the right direction but not enough.

TURN COORDINATION: OK, turn rates good, low workload on missed approach.

THRUST CONTROL: Pitching due to collective could be working for us. Yaw due to collective is added workload, required retrimming.

TASK PERFORMANCE: All good. Only special control technique is to anticipate required pitch change to hold speed with power changes.

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S30	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.26 in./20 knots	4		**PILOT:**	G
LATERAL POSITION GRADIENT:	0.50 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	206-208	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Needs more help with decoupling. Directional characteristics weak.

REASON FOR RATING: Needs and warrants improvement — more coupling, directional stiffness and symmetry, pedal sensitivity.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S30	PILOT RATING (NO TURBULENCE)		ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.26 in./20 knots			PILOT:	H
LATERAL POSITION GRADIENT:	0.50 in./15°	6		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	RUNS:	244-246	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Predictable responses.

OBJECTIONABLE FEATURES: Airspeed excursions outside acceptable limits. Required large control throws, don't like to move controls that extent to fly a helicopter.

REASON FOR RATING: Extensive compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S30	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.26 in./20 knots		6	**PILOT:**	H
LATERAL POSITION GRADIENT:	0.50 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	244-246	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Large control throws.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Managed to stay with 10 knot target barely.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S30	PILOT RATING (NO TURBULENCE)		ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.26 in./20 knots			PILOT:	K
LATERAL POSITION GRADIENT:	0.50 in./15°	3		FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	RUNS:	339-341	SCAS:	AC

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Such a nice configuration did deceleration and descent at same time, got lazy on first try and forgot to do missed approach! Airplane stayed right where you put it, verv little problem with it in any way.

OBJECTIONABLE FEATURES:

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S30	**PILOT RATING (IN TURBULENCE)**		**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	-0.26 in./20 knots	3½		**PILOT:**	K
LATERAL POSITION GRADIENT:	0.50 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	339-341	**SCAS:**	AC

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Enough additional workload for 1/2 rating.

SPECIFICS:

TRIM: Sometimes used mag brake, but often would just hold against the force in turns, a nice feature.

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Some speed deviations, but I'll blame that on me.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID: S31	**PILOT RATING (NO TURBULENCE)**	**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots	4	**PILOT:**	H
LATERAL POSITION GRADIENT: 0.00 in./15°		**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT: -0.86 in./15°	**RUNS:** 247-249	**SCAS:**	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES: Predictable responses, attitude hold feature.

OBJECTIONABLE FEATURES: Lateral/longitudinal coupling, required significant attitude changes nose-up for right turn, nose-down for left turn to hold airspeed.

REASON FOR RATING: Minor but annoying deficiencies, moderate compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S31	PILOT RATING (IN TURBULENCE) 5	ROTOR: ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots		PILOT: K
LATERAL POSITION GRADIENT:	0.00 in./15°		FORCE FEEL: ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	RUNS: 336-338	SCAS: RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Speed control in turns, apparent coupling.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE: When making turn and power change got coupling into attitude, would have to constantly change attitude to get speed where I wanted it. Task performance demanding but OK.

EFFECTS OF TURBULENCE: Turbulence made it harder to maintain steady attitudes.

CONFIGURATION ID: S31	PILOT RATING (NO TURBULENCE)	ROTOR:	ARTICULATED
LONGITUDINAL POSITION GRADIENT: 0.00 in./20 knots		PILOT:	K
LATERAL POSITION GRADIENT: 0.00 in./15°	4½	FORCE FEEL:	ON
DIRECTIONAL POSITION GRADIENT: -0.86 in./15°	RUNS: 336-338	SCAS:	RCAH

NO-TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES: Response of speed to pitch attitude change is slow.

REASON FOR RATING:

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL: Expected to see speed change more quickly, would have to put in another increment of attitude.

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE:

CONFIGURATION ID:	S31	**PILOT RATING (IN TURBULENCE)**	4½	**ROTOR:**	ARTICULATED
LONGITUDINAL POSITION GRADIENT:	0.00 in./20 knots			**PILOT:**	H
LATERAL POSITION GRADIENT:	0.00 in./15°			**FORCE FEEL:**	ON
DIRECTIONAL POSITION GRADIENT:	-0.86 in./15°	**RUNS:**	247-249	**SCAS:**	RCAH

TURBULENCE COMMENTS

SUMMARY:

GOOD FEATURES:

OBJECTIONABLE FEATURES:

REASON FOR RATING: Considerable compensation.

SPECIFICS:

TRIM:

PITCH RESPONSE:

ROLL RESPONSE:

SPEED CONTROL:

TURN COORDINATION:

THRUST CONTROL:

TASK PERFORMANCE:

EFFECTS OF TURBULENCE: Seemed to aggravate coupling problems.

APPENDIX D

PERFORMANCE AND CONTROL USAGE MEASURES

TABLE D1.- STANDARD DEVIATION MEASURES OF FLIGHT CONTROL ACTIVITY AND CONTROL PRECISION

(a) Configuration S01

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	2	Descent	0.107	0.046	0.137	0.039	2.39	1.47	2.37	1.93	4.46	0.48
		Missed approach	0.036	0.080	0.136	0.006	1.95	1.38	--	1.67	2.95	0.57
G	138	Descent	0.098	0.120	0.123	0.069	1.41	2.15	2.65	1.13	3.63	1.00
		Missed approach	0.080	0.018	0.177	0.064	1.30	2.42	--	1.34	1.99	1.13
K	168	Descent	0.200	0.615	0.050	0.082	2.94	1.30	8.79	2.82	7.25	1.28
		Missed approach	0.184	0.674	0.229	0.062	1.73	7.52	--	1.64	7.35	1.29
H	187	Descent	0.094	0.036	0.120	0.025	0.86	1.94	1.41	0.63	1.19	0.49
		Missed approach	0.198	0.012	0.225	0.095	3.14	9.56	--	1.50	2.91	1.20
M	297	Descent	0.085	0.097	0.223	0.027	1.81	3.83	5.00	2.05	2.54	0.87
		Missed approach	0.144	0.010	0.248	0.022	2.61	6.76	--	2.63	3.81	1.40
K	310	Descent	0.089	0.014	0.120	0.038	0.084	1.39	8.99	0.55	1.04	0.62
		Missed approach	0.187	0.758	0.248	0.027	3.27	8.04	--	2.58	10.25	1.30
TURBULENCE												
G	3	Descent	0.054	0.112	0.221	0.140	1.11	2.95	1.57	1.27	2.93	2.69
		Missed approach	0.233	0.184	0.162	0.060	3.98	1.74	--	4.12	4.42	4.82
H	10	Descent	0.071	0.335	0.130	0.018	1.52	1.45	4.91	1.89	4.73	0.66
		Missed approach	0.096	0.766	0.181	0.062	1.40	8.12	--	1.67	6.80	1.28
G	139	Descent	0.097	0.165	0.130	0.047	2.10	1.51	1.17	1.83	2.88	1.29
		Missed approach	0.054	0.011	0.133	0.028	1.42	2.38	--	1.64	2.50	1.25
K	169	Descent	0.104	0.656	0.110	0.071	1.67	1.94	2.18	1.01	7.47	1.24
		Missed approach	0.145	0.158	0.210	0.050	2.21	3.10	--	2.13	3.88	1.44
H	188	Descent	0.087	0.069	0.120	0.068	0.82	2.26	1.86	1.03	2.10	1.40
		Missed approach	0.104	0.023	0.161	0.036	0.92	6.66	--	1.03	1.84	2.45
M	298	Descent	0.160	0.103	0.183	0.032	3.16	1.76	1.70	3.46	5.15	0.89
		Missed approach	0.276	0.236	0.269	0.087	4.28	9.34	--	1.98	6.43	1.60
K	311	Descent	0.120	0.010	0.085	0.087	1.55	1.96	2.97	1.91	3.38	1.69
		Missed approach	0.143	0.218	0.182	0.025	2.61	3.48	--	2.55	4.72	2.01

TABLE D1.- Continued.

(b) Configuration S02

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	5	Descent	0.098	0.018	0.076	0.056	1.95	1.56	6.40	2.75	3.83	0.95
		Missed approach	0.084	0.361	0.224	0.069	2.45	4.24	--	3.10	5.65	1.67
H	12	Descent	0.054	0.027	0.103	0.023	0.81	1.54	4.40	1.43	1.65	0.41
		Missed approach	0.162	0.604	0.245	0.028	2.91	8.16	--	2.26	7.89	0.76
G	147	Descent	0.070	0.147	0.171	0.097	1.02	2.55	7.99	1.65	3.28	1.79
		Missed approach	0.080	0.049	0.202	0.110	1.98	2.43	--	2.67	3.56	1.82
K	171	Descent	0.127	0.316	0.162	0.053	1.52	1.65	5.56	1.81	4.67	0.79
		Missed approach	0.147	0.718	0.243	0.103	1.63	5.49	--	1.59	6.78	1.02
H	193	Descent	0.066	0.016	0.057	0.044	0.72	1.37	2.91	0.78	1.08	0.59
		Missed approach	0.134	0.091	0.174	0.088	3.32	8.89	--	2.60	2.47	0.97
M	300	Descent	0.113	0.032	0.240	0.025	1.74	3.70	5.29	2.25	2.81	0.73
		Missed approach	0.142	0.011	0.260	0.011	2.73	6.24	--	3.60	4.51	1.35
K	358	Descent	0.093	0.112	0.181	0.058	0.99	2.72	1.76	1.82	2.22	1.09
		Missed approach	0.174	1.024	0.119	0.042	2.17	8.35	--	2.32	9.85	1.35
TURBULENCE												
G	7	Descent	0.133	0.133	0.139	0.069	2.48	2.06	1.67	3.12	4.36	1.39
		Missed approach	0.114	0.745	0.232	0.046	2.05	4.71	--	1.86	8.39	1.26
H	13	Descent	0.077	0.017	0.142	0.031	1.30	2.67	1.49	1.27	2.21	0.93
		Missed approach	0.132	0.327	0.165	0.069	3.64	4.94	--	4.32	6.02	2.78
G	148	Descent	0.135	0.185	0.134	0.045	2.27	1.20	3.63	3.84	4.19	0.99
		Missed approach	0.081	0.042	0.153	0.027	2.12	1.97	--	2.48	2.34	1.68
K	172	Descent	0.138	0.420	0.118	0.054	1.49	1.82	3.29	2.97	4.66	1.21
		Missed approach	0.153	0.666	0.156	0.066	2.00	2.05	--	2.88	6.49	1.49
H	194	Descent	0.072	0.012	0.103	0.044	0.58	2.31	6.07	2.22	1.95	1.74
		Missed approach	0.124	0.012	0.172	0.046	1.16	7.52	--	1.46	1.58	1.78
M	301	Descent	0.166	0.010	0.210	0.068	2.05	1.80	1.15	1.81	4.27	1.72
		Missed approach	0.103	0.011	0.193	0.009	2.67	2.14	--	5.40	4.35	2.22
K	359	Descent	0.133	0.194	0.143	0.050	1.94	1.63	1.36	3.71	4.69	0.98
		Missed approach	0.214	0.739	0.272	0.051	3.76	5.82	--	5.64	9.52	3.62

TABLE D1.- Continued.

(c) Configuration S03

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	25	Descent	0.073	0.013	0.176	0.029	0.77	3.23	2.37	0.94	1.59	0.86
		Missed approach	0.087	0.065	0.165	0.039	2.74	9.59	--	2.90	2.80	0.53
K	177	Descent	0.142	0.231	0.302	0.102	1.20	4.92	6.20	0.98	4.03	1.52
		Missed approach	0.116	0.670	0.208	0.058	2.41	8.63	--	1.80	7.22	1.81
M	346	Descent	0.052	0.011	0.133	0.030	0.75	2.65	3.88	1.10	1.25	0.58
		Missed approach	0.172	0.012	0.326	0.046	3.09	8.92	--	2.46	4.90	1.73
TURBULENCE												
H	26	Descent	0.056	0.118	0.097	0.059	0.77	1.79	6.71	0.91	3.21	1.03
		Missed approach	0.110	0.434	0.105	0.037	1.77	5.09	--	3.20	3.94	1.78
G	33	Descent	0.133	0.219	0.137	0.112	2.38	2.24	4.78	2.31	5.67	2.48
		Missed approach	0.153	0.258	0.351	0.076	3.70	4.16	--	4.27	7.52	2.12
K	179	Descent	0.063	0.137	0.170	0.066	1.37	2.28	2.73	1.27	3.74	1.39
		Missed approach	0.160	0.586	0.242	0.051	1.87	6.51	--	1.74	6.66	1.82
M	347	Descent	0.277	0.337	0.198	0.091	4.13	2.58	10.94	4.06	8.17	2.44
		Missed approach	0.152	0.011	0.280	0.012	3.13	3.92	--	3.22	4.04	3.36

TABLE D1.- Continued.

(d) Configuration S04

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	62	Descent	0.088	0.331	0.211	0.159	1.62	1.72	5.00	1.82	5.72	2.77
		Missed approach	0.114	0.551	0.225	0.034	2.40	4.31	--	3.07	7.17	0.53
H	96	Descent	0.058	0.033	0.183	0.068	0.69	1.75	7.30	2.46	1.25	2.61
		Missed approach	0.101	0.011	0.185	0.042	1.19	8.14	--	0.37	1.14	1.36
K	252	Descent	0.173	0.139	0.227	0.069	2.03	3.55	3.75	1.49	2.90	1.10
		Missed approach	0.147	0.816	0.282	0.050	2.41	6.65	--	1.63	9.03	1.71
M	375	Descent	0.107	0.166	0.154	0.096	1.11	2.03	1.37	3.37	3.14	1.41
		Missed approach	0.132	0.011	0.196	0.056	2.47	7.51	--	2.54	3.58	1.48
TURBULENCE												
G	63	Descent	0.141	0.292	0.178	0.048	3.35	2.34	1.21	4.82	7.19	0.96
		Missed approach	0.066	0.494	0.217	0.039	1.41	4.98	--	1.65	6.47	1.36
H	97	Descent	0.112	0.106	0.198	0.087	1.43	3.77	2.51	2.29	3.34	1.51
		Missed approach	0.263	0.175	0.325	0.024	2.94	9.20	--	4.59	5.69	1.94
K	253	Descent	0.177	0.011	0.211	0.097	2.13	2.59	6.12	3.85	4.25	2.06
		Missed approach	0.256	0.587	0.347	0.017	3.50	8.92	--	3.65	7.33	1.38
M	376	Descent	0.169	0.045	0.355	0.075	1.82	3.84	5.38	2.01	3.24	1.41
		Missed approach	0.150	0.011	0.254	0.036	1.91	5.33	--	1.90	3.85	1.53

TABLE D1.- Continued.

(e) Configuration S05

Pilot	Run	Segment	Standard deviation δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	41	Descent	0.131	0.385	0.277	0.082	1.62	3.38	1.02	1.38	5.56	2.89
		Missed approach	0.091	0.500	0.196	0.026	2.01	4.11	--	1.59	4.09	1.04
H	46	Descent	0.077	0.101	0.160	0.022	0.97	1.83	3.00	0.74	2.07	1.21
		Missed approach	0.224	0.020	0.279	0.114	4.15	12.35	--	2.86	5.76	2.61
G	92	Descent	0.123	0.334	0.169	0.067	1.42	1.59	1.45	1.02	4.24	3.33
		Missed approach	0.107	0.631	0.173	0.061	1.23	4.73	--	1.60	6.54	2.18
H	108	Descent	0.041	0.094	0.111	0.040	0.48	1.99	5.97	0.88	2.03	1.71
		Missed approach	0.232	0.045	0.218	0.085	3.81	10.78	--	1.44	3.19	1.94
K	224	Descent	0.103	0.203	0.103	0.049	1.28	1.29	14.73	1.15	3.16	2.62
		Missed approach	0.158	0.196	0.207	0.041	1.51	4.92	--	2.04	3.26	2.59
K	316	Descent	0.066	0.024	0.070	0.030	0.96	1.54	1.20	1.75	1.42	1.66
		Missed approach	0.160	0.779	0.089	0.046	2.98	7.73	--	1.88	10.10	1.97
M	349	Descent	0.124	0.010	0.206	0.032	1.62	2.51	2.70	0.96	2.73	1.42
		Missed approach	0.138	0.011	0.313	0.073	4.06	7.74	--	3.71	6.48	2.90
TURBULENCE												
G	42	Descent	0.154	0.251	0.177	0.054	2.55	2.62	1.86	3.37	5.90	2.79
		Missed approach	0.126	0.148	0.270	0.063	2.40	3.26	--	2.36	3.77	4.52
H	47	Descent	0.053	0.011	0.142	0.037	0.69	2.73	1.91	1.00	1.83	1.47
		Missed approach	0.164	0.017	0.176	0.064	1.47	8.61	--	1.97	1.46	1.46
G	93	Descent	0.154	0.073	0.159	0.091	2.79	1.44	1.81	2.43	4.25	4.61
		Missed approach	0.137	0.011	0.202	0.044	2.42	1.74	--	1.64	3.65	2.58
H	109	Descent	0.113	0.075	0.133	0.049	1.05	1.33	12.58	1.85	1.98	2.33
		Missed approach	0.113	0.364	0.144	0.057	1.48	2.63	--	1.70	4.65	1.43
K	225	Descent	0.147	0.338	0.171	0.082	1.23	2.75	5.82	2.77	4.73	3.25
		Missed approach	0.058	0.698	0.122	0.042	0.93	6.67	--	1.12	5.62	3.20
K	317	Descent	0.123	0.146	0.180	0.045	1.42	3.36	3.83	2.42	3.05	2.66
		Missed approach	0.252	0.949	0.355	0.133	2.40	8.00	--	3.12	10.01	3.68
M	350	Descent	0.151	0.011	0.389	0.101	1.96	4.21	2.51	1.90	3.78	3.55
		Missed approach	0.245	0.011	0.289	0.066	2.36	5.70	--	3.43	4.07	3.46

TABLE D1.- Continued.

(f) Configuration S06

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	75	Descent	0.139	0.324	0.265	0.145	2.43	2.64	5.45	2.77	5.05	5.92
		Missed approach	0.075	0.011	0.201	0.084	1.78	2.85	--	1.43	2.03	4.20
H	126	Descent	0.090	0.092	0.116	0.049	0.72	2.74	11.28	1.11	2.10	2.64
		Missed approach	0.215	0.150	0.207	0.063	3.90	6.78	--	2.54	4.56	2.17
K	261	Descent	0.131	0.011	0.249	0.070	1.49	3.59	1.81	1.49	1.97	3.04
		Missed approach	0.183	0.011	0.218	0.038	1.81	3.02	--	1.97	2.43	3.08
M	378	Descent	0.091	0.012	0.183	0.056	1.03	2.51	1.67	1.28	1.78	2.58
		Missed approach	0.152	0.011	0.284	0.071	3.08	5.95	--	3.72	5.20	3.55
TURBULENCE												
G	76	Descent	0.111	0.731	0.321	0.123	2.09	4.36	4.58	2.41	7.94	5.78
		Missed approach	0.078	1.072	0.181	0.046	1.51	6.91	--	1.36	11.12	2.14
H	127	Descent	0.108	0.033	0.177	0.056	0.80	3.80	4.54	1.45	1.63	4.34
		Missed approach	0.164	0.011	0.145	0.063	1.80	8.59	--	2.13	2.04	2.19
K	262	Descent	0.115	0.034	0.142	0.050	1.03	1.99	4.71	0.97	2.94	2.77
		Missed approach	0.253	0.575	0.229	0.066	2.91	5.00	--	3.64	7.29	5.03
M	379	Descent	0.180	0.016	0.169	0.042	1.89	2.38	0.94	2.03	3.66	2.38
		Missed approach	0.182	0.078	0.187	0.052	2.14	7.40	--	1.51	4.29	1.42

TABLE D1.- Continued.

(g) Configuration S07

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	35	Descent	0.171	0.120	0.218	0.060	3.91	2.63	1.36	6.99	7.70	4.02
		Missed approach	0.184	0.684	0.275	0.119	4.04	6.48	--	4.84	9.25	5.70
H	123	Descent	0.070	0.083	0.118	0.035	0.77	1.47	4.35	0.72	1.84	1.37
		Missed approach	0.157	0.012	0.318	0.083	1.21	6.45	--	2.81	2.99	4.89
K	181	Descent	0.102	0.716	0.166	0.077	1.18	3.52	3.16	1.62	8.47	3.02
		Missed approach	0.143	0.680	0.211	0.073	1.64	5.73	--	1.28	6.43	3.03
M	352	Descent	0.238	0.379	0.308	0.071	3.36	4.91	1.20	6.40	7.15	2.57
		Missed approach	0.256	0.385	0.334	0.124	3.92	7.67	--	8.40	9.60	5.80
TURBULENCE												
G	36	Descent	0.098	0.151	0.229	0.064	2.16	2.18	0.87	4.11	4.12	3.62
		Missed approach	0.170	0.594	0.306	0.172	5.62	4.97	--	5.65	11.74	7.12
H	124	Descent	0.101	0.026	0.240	0.061	0.81	3.42	2.34	2.39	1.93	2.5[illegible]
		Missed approach	0.262	0.012	0.237	0.060	3.16	9.53	--	2.68	3.86	2.54
K	182	Descent	0.132	0.400	0.219	0.068	1.79	2.77	3.46	2.06	5.54	2.68
		Missed approach	0.179	0.701	0.275	0.060	2.63	6.17	--	2.65	7.26	3.54
M	353	Descent	0.294	0.118	0.526	0.090	3.79	6.47	2.22	2.77	5.93	2.62
		Missed Approach	0.574	0.578	0.370	0.064	4.29	8.85	--	12.17	8.33	14.02

TABLE D1.- Continued.

(h) Configuration S08

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	135	Descent	0.112	0.055	0.123	0.055	1.91	4.57	4.52	2.50	3.41	3.65
		Missed approach	0.194	0.012	0.151	0.034	2.42	6.54	--	3.13	3.64	2.62
G	141	Descent	0.077	0.127	0.337	0.111	1.25	6.11	9.65	1.67	2.70	8.30
		Missed approach	0.123	0.551	0.235	0.130	2.90	4.96	--	3.30	6.06	6.97
K	313	Descent	0.122	0.189	0.090	0.071	1.66	1.56	7.85	1.95	3.96	4.10
		Missed approach	0.216	0.921	0.147	0.015	3.40	7.35	--	1.66	11.32	1.91
TURBULENCE												
H	136	Descent	0.071	0.289	0.103	0.033	0.76	2.15	2.23	1.41	4.39	2.25
		Missed approach	0.116	0.052	0.161	0.046	1.38	6.57	--	2.28	2.08	2.36
G	142	Descent	0.104	0.133	0.121	0.047	1.15	1.79	3.10	2.48	3.39	2.69
		Missed approach	0.092	0.046	0.168	0.029	1.88	1.63	--	1.93	3.06	2.27
K	314	Descent	0.108	0.065	0.210	0.071	1.18	5.80	3.74	2.51	3.18	3.84
		Missed approach	0.169	0.932	0.217	0.078	1.78	7.72	--	1.60	8.12	2.48

TABLE D1.- Continued.

(i) Configuration S09

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	55	Descent	0.116	0.283	0.094	0.022	1.39	2.03	2.08	1.07	3.26	1.50
		Missed approach	0.113	0.441	0.216	0.096	1.76	3.19	--	1.61	5.57	1.54
G	90	Descent	0.118	0.150	0.164	0.101	1.29	1.38	2.70	1.19	1.26	3.55
		Missed approach	0.283	0.043	0.272	0.027	2.63	2.22	--	2.34	4.64	3.00
K	233	Descent	0.226	0.808	0.376	0.138	1.37	4.30	15.28	1.49	6.70	2.98
		Missed approach	0.198	0.460	0.219	0.080	1.47	1.37	--	1.41	3.34	2.48
TURBULENCE												
H	56	Descent	0.140	0.263	0.101	0.049	1.22	1.66	2.74	1.75	4.06	2.23
		Missed approach	0.134	0.553	0.148	0.057	2.99	7.30	--	2.00	5.77	1.46
G	89	Descent	0.178	0.058	0.147	0.105	2.15	1.32	1.07	2.33	3.56	3.19
		Missed approach	0.177	0.083	0.221	0.098	2.83	2.75	--	3.34	3.39	4.98
K	234	Descent	0.207	0.910	0.246	0.215	1.87	3.55	3.37	3.82	6.29	2.64
		Missed approach	0.248	0.750	0.132	0.085	2.42	6.41	--	2.34	8.00	3.77

TABLE D1.- Continued.

(j) Configuration S10

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	72	Descent	0.106	0.311	0.254	0.067	1.86	3.84	2.30	2.78	4.60	3.61
		Missed approach	0.111	0.164	0.144	0.016	2.17	1.88	--	7.53	4.41	5.78
H	105	Descent	0.221	0.229	0.206	0.064	2.07	2.11	2.22	2.66	4.86	3.95
		Missed approach	0.259	0.202	0.318	0.053	1.42	4.79	--	2.06	4.34	2.66
G	211	Descent	0.228	0.389	0.237	0.085	3.26	2.59	3.80	4.35	6.76	6.56
		Missed approach	0.102	0.011	0.120	0.065	1.34	1.61	--	1.89	2.61	3.39
K	270	Descent	0.166	0.072	0.168	0.126	1.72	2.08	2.74	1.90	3.36	4.42
		Missed approach	0.298	0.898	0.228	0.022	3.23	8.60	--	5.23	7.59	3.91
H	325	Descent	0.226	0.112	0.353	0.103	1.98	3.50	2.82	2.72	3.13	4.46
		Missed approach	0.353	0.166	0.442	0.073	1.28	8.34	--	2.34	3.56	6.99
TURBULENCE												
G	73	Descent	0.124	0.050	0.214	0.107	2.18	2.81	0.96	4.66	3.43	3.17
		Missed approach	0.261	0.735	0.376	0.119	6.09	7.15	--	12.64	13.80	9.15
H	106	Descent	0.243	0.053	0.386	0.085	1.82	3.97	4.30	5.89	3.67	9.80
		Missed approach	0.205	0.406	0.221	0.026	2.57	3.84	--	3.77	6.77	2.38
G	212	Descent	0.198	0.060	0.151	0.099	1.92	1.27	5.89	4.99	3.50	3.36
		Missed approach	0.123	0.128	0.161	0.040	1.66	0.89	--	2.33	2.61	1.34
K	271	Descent	0.205	0.198	0.100	0.183	1.56	1.15	5.18	2.51	3.87	3.97
		Missed approach	0.243	0.907	0.308	0.185	2.53	8.50	--	1.75	7.38	4.25
H	326	Descent	0.148	0.033	0.272	0.090	1.50	2.58	5.27	2.79	2.09	6.51
		Missed approach	0.420	0.333	0.386	0.211	6.79	7.76	--	5.47	6.40	8.14

TABLE D1.- Continued.

(k) Configuration S11

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	204	Descent	0.198	0.188	0.205	0.142	1.31	3.90	5.75	1.50	2.94	5.76
		Missed approach	0.328	0.417	0.434	0.100	3.64	4.16	--	4.34	4.92	6.07
H	238	Descent	0.203	0.142	0.242	0.077	1.93	1.94	12.63	2.15	3.23	3.30
		Missed approach	0.504	0.303	0.320	0.171	3.84	8.30	--	5.61	5.99	5.42
TURBULENCE												
G	205	Descent	0.269	0.016	0.340	0.151	1.90	2.79	0.51	1.74	2.09	9.38
		Missed approach	0.199	0.011	0.360	0.059	2.24	4.08	--	2.59	3.12	5.89
H	239	Descent	0.139	0.194	0.275	0.084	1.26	2.03	16.02	1.99	2.71	5.69
		Missed approach	0.274	0.416	0.658	0.106	3.22	9.67	--	6.39	5.22	11.25

TABLE D1.- Continued.

(1) Configuration S13

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	17	Descent	0.076	0.044	0.166	0.019	0.73	1.74	3.24	0.64	1.41	0.37
		Missed approach	0.160	0.046	0.224	0.011	3.12	10.08	--	3.20	3.48	1.18
G	111	Descent	0.104	0.325	0.203	0.120	1.75	2.60	1.38	2.03	5.60	2.12
		Missed approach	0.087	0.383	0.163	0.073	2.13	3.46	--	1.84	4.37	1.26
G	144	Descent	0.129	0.117	0.178	0.207	1.45	2.26	3.24	2.27	3.09	3.92
		Missed approach	0.104	0.017	0.178	0.112	2.45	1.73	--	2.14	3.86	1.68
K	174	Descent	0.120	0.087	0.116	0.025	1.01	1.41	6.88	0.53	2.53	0.43
		Missed approach	0.122	0.745	0.191	0.055	0.86	4.90	--	0.99	7.33	0.80
H	190	Descent	0.060	0.060	0.120	0.028	0.59	1.54	0.94	0.46	1.90	0.40
		Missed approach	0.115	0.013	0.171	0.044	1.08	7.45	--	1.00	1.51	1.24
M	303	Descent	0.260	0.010	0.258	0.068	6.04	3.40	0.89	5.83	9.08	2.98
		Missed approach	0.198	0.011	0.152	0.015	2.05	4.51	--	2.23	3.69	1.78
K	319	Descent	0.149	0.043	0.195	0.088	0.97	3.44	1.73	0.72	1.52	1.26
		Missed approach	0.178	0.481	0.189	0.028	2.11	4.10	--	2.13	7.45	0.81
TURBULENCE												
H	20	Descent	0.113	0.037	0.200	0.020	1.18	2.03	4.03	2.14	1.99	0.81
		Missed approach	0.100	0.758	0.179	0.064	1.23	7.30	--	1.33	7.23	1.86
G	112	Descent	0.107	0.218	0.136	0.101	1.66	1.69	2.88	1.42	4.92	1.78
		Missed approach	0.139	0.011	0.152	0.052	1.97	2.09	--	2.23	3.15	1.82
G	145	Descent	0.128	0.346	0.212	0.112	3.03	2.47	1.27	3.75	5.35	1.94
		Missed approach	0.076	0.040	0.143	0.029	1.52	2.18	--	1.23	2.78	1.11
K	175	Descent	0.234	0.255	0.201	0.048	2.40	2.41	5.14	3.71	5.62	1.05
		Missed approach	0.144	0.693	0.101	0.068	1.58	1.21	--	1.44	6.87	1.22
H	191	Descent	0.070	0.011	0.155	0.025	1.02	2.23	1.42	1.08	1.48	0.97
		Missed approach	0.225	0.083	0.236	0.069	3.38	9.99	--	1.29	2.22	2.31
M	304	Descent	0.283	0.101	0.303	0.039	3.86	4.34	2.88	2.23	7.63	1.30
		Missed approach	0.330	0.011	0.363	0.057	3.31	6.10	--	5.52	3.90	3.38
K	320	Descent	0.135	0.066	0.190	0.088	0.87	1.93	4.32	2.31	2.64	1.71
		Missed approach	0.189	0.920	0.266	0.046	1.63	6.03	--	1.59	9.32	1.51

TABLE D1.- Continued.

(m) Configuration S14

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	22	Descent	0.114	0.157	0.196	0.018	1.80	2.42	2.91	2.55	3.24	0.99
		Missed approach	0.107	0.083	0.092	0.011	1.18	2.55	--	1.55	2.28	0.51
G	114	Descent	0.096	0.165	0.240	0.179	1.23	3.58	1.45	0.85	2.59	2.98
		Missed approach	0.136	0.173	0.186	0.058	2.93	3.94	--	2.95	5.18	0.88
TURBULENCE												
H	23	Descent	0.129	0.107	0.218	0.036	1.21	2.90	1.95	1.80	3.87	1.16
		Missed approach	0.163	0.224	0.247	0.016	1.74	4.38	--	3.75	4.20	1.96
G	115	Descent	0.185	0.498	0.237	0.062	2.95	2.95	4.41	3.48	6.76	1.68
		Missed approach	0.087	0.608	0.201	0.092	2.02	5.84	--	3.09	8.45	2.02

TABLE D1.- Continued.

(n) Configuration S15

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	28	Descent	0.074	0.107	0.138	0.032	0.83	1.43	0.90	0.97	2.00	0.65
		Missed approach	0.121	0.409	0.109	0.047	1.36	5.16	--	0.75	4.18	1.07
G	117	Descent	0.120	0.424	0.304	0.261	1.39	4.55	6.33	1.55	5.68	5.04
		Missed approach	0.088	0.034	0.150	0.022	2.19	1.75	--	1.64	3.23	0.69
TURBULENCE												
H	29	Descent	0.112	0.083	0.201	0.065	1.00	3.56	2.38	2.25	1.42	1.22
		Missed approach	0.197	0.357	0.273	0.025	3.41	7.04	--	2.59	6.95	1.30
G	118	Descent	0.138	0.339	0.203	0.088	1.84	2.06	2.76	2.03	6.05	1.62
		Missed approach	0.119	0.012	0.212	0.080	2.26	2.70	--	1.36	3.03	1.92

TABLE D1.- Continued.

(o) Configuration S16

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	65	Descent	0.112	0.061	0.166	0.063	2.32	1.74	0.73	3.21	4.61	1.14
		Missed approach	0.095	0.012	0.117	0.008	1.78	1.73	--	1.98	2.99	0.89
H	99	Descent	0.124	0.018	0.150	0.034	0.84	1.86	1.16	0.64	1.88	0.86
		Missed approach	0.194	0.070	0.187	0.032	3.06	8.06	--	2.46	2.62	1.96
K	255	Descent	0.278	0.641	0.227	0.068	3.29	4.10	7.47	2.70	7.73	1.06
		Missed approach	0.204	0.011	0.148	0.011	2.46	2.92	--	2.18	3.57	1.29
TURBULENCE												
G	66	Descent	0.170	0.048	0.191	0.089	3.29	3.43	1.47	3.25	6.73	2.18
		Missed approach	0.153	0.587	0.248	0.070	3.86	5.40	--	4.91	5.86	5.62
H	100	Descent	0.135	0.079	0.202	0.035	0.76	3.00	2.57	1.65	1.97	0.92
		Missed approach	0.141	0.049	0.203	0.046	1.36	6.73	--	1.41	2.00	1.58
K	256	Descent	0.203	0.055	0.254	0.087	1.85	3.11	5.89	3.01	2.95	1.83
		Missed approach	0.240	0.012	0.240	0.073	2.54	4.53	--	3.74	4.02	2.13

TABLE D1.- Continued.

(p) Configuration S17

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	52	Descent	0.132	0.036	0.231	0.054	1.35	3.50	1.47	1.64	2.68	4.21
		Missed approach	0.137	0.583	0.268	0.083	3.04	5.92	--	2.92	8.05	3.21
G	120	Descent	0.110	0.329	0.267	0.054	1.99	4.05	2.75	3.13	5.49	1.90
		Missed approach	0.096	0.394	0.184	0.032	1.45	4.14	--	1.45	5.91	1.92
K	230	Descent	0.183	0.257	0.246	0.075	1.56	2.42	0.67	1.41	2.74	3.72
		Missed approach	0.170	0.776	0.237	0.069	1.56	4.89	--	0.74	8.28	1.13
TURBULENCE												
H	53	Descent	0.159	0.062	0.253	0.059	1.35	4.31	1.50	3.17	2.75	4.01
		Missed approach	0.374	0.638	0.311	0.114	5.63	10.02	--	2.74	6.14	6.54
G	121	Descent	0.079	0.274	0.165	0.041	1.33	1.81	1.72	1.33	4.30	1.61
		Missed approach	0.132	0.014	0.201	0.037	1.45	2.93	--	2.54	2.07	2.35
K	231	Descent	0.173	0.472	0.112	0.069	1.46	1.91	3.42	1.81	7.07	2.58
		Missed approach	0.164	0.677	0.133	0.037	1.80	5.08	--	3.15	7.00	3.00

TABLE D1.- Continued.

(q) Configuration S18

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	82	Descent	0.084	0.185	0.198	0.047	1.01	2.77	2.11	3.09	3.60	3.94
		Missed approach	0.131	0.569	0.155	0.044	2.27	5.64	--	2.17	6.83	1.64
H	132	Descent	0.096	0.015	0.099	0.023	0.63	1.06	7.64	0.48	0.72	1.22
		Missed approach	0.070	0.011	0.131	0.049	0.65	5.79	--	0.59	0.89	1.99
K	264	Descent	0.134	0.102	0.243	0.056	1.11	3.39	1.51	2.18	2.40	1.92
		Missed approach	0.202	0.011	0.161	0.018	1.65	4.03	--	1.22	2.29	3.04
TURBULENCE												
G	83	Descent	0.109	0.586	0.245	0.095	2.03	3.17	3.25	2.11	8.37	4.95
		Missed approach	0.132	0.701	0.333	0.104	2.07	6.37	--	2.44	8.60	4.88
H	133	Descent	0.113	0.103	0.169	0.054	0.68	2.79	9.86	1.50	2.22	2.85
		Missed approach	0.143	0.026	0.240	0.037	3.04	5.92	--	3.68	3.90	2.83
K	265	Descent	0.174	0.011	0.255	0.042	1.27	3.44	1.37	1.59	2.14	3.01
		Missed approach	0.264	0.012	0.291	0.031	2.46	5.62	--	3.44	5.87	4.08

TABLE D1.- Continued.

(r) Configuration S21

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	49	Descent	0.099	0.046	0.158	0.050	1.50	3.13	9.70	2.47	2.85	1.11
		Missed approach	0.072	0.025	0.154	0.048	1.05	7.30	--	1.31	1.37	1.65
G	85	Descent	0.191	0.295	0.204	0.151	3.95	3.50	3.01	5.56	6.63	2.37
		Missed approach	0.083	0.054	0.065	0.009	2.08	1.23	--	1.96	3.14	0.81
K	227	Descent	0.108	0.427	0.207	0.121	1.27	2.19	6.15	1.26	4.70	1.59
		Missed approach	0.147	0.011	0.271	0.056	1.60	3.89	--	2.02	2.64	1.11
M	372	Descent	0.103	0.058	0.189	0.039	0.96	2.90	1.01	5.43	1.79	0.50
		Missed approach	0.107	0.040	0.213	0.059	1.74	7.54	--	1.89	3.42	1.33
TURBULENCE												
H	50	Descent	0.079	0.011	0.130	0.035	0.89	1.68	1.05	2.62	2.58	0.75
		Missed approach	0.300	0.351	0.392	0.094	3.83	11.66	--	4.02	7.57	1.57
G	86	Descent	0.114	0.018	0.213	0.020	1.93	3.13	2.54	1.77	3.14	1.00
		Missed approach	0.239	0.012	0.258	0.039	4.14	3.23	--	5.33	7.71	1.21
K	228	Descent	0.099	0.197	0.147	0.054	1.17	1.47	10.96	2.46	3.31	0.84
		Missed approach	0.143	0.739	0.192	0.070	1.90	7.60	--	2.18	8.00	1.65
M	373	Descent	0.058	0.011	0.264	0.073	0.76	3.91	0.99	1.40	2.00	1.17
		Missed approach	0.174	0.010	0.258	0.044	3.10	7.10	--	3.68	4.09	1.41

TABLE D1.- Continued.

(s) Configuration S24

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	78	Descent	0.090	0.266	0.141	0.043	0.82	1.14	0.91	2.77	3.79	0.75
		Missed approach	0.082	0.209	0.105	0.066	0.86	0.98	--	1.54	2.69	1.23
H	129	Descent	0.014	0.148	0.141	0.034	0.10	1.57	3.33	1.02	1.92	0.19
		Missed approach	0.149	0.040	0.394	0.024	1.13	4.15	--	0.98	2.22	0.64
G	220	Descent	0.048	0.351	0.245	0.042	0.40	2.10	3.61	1.69	3.47	0.57
		Missed approach	0.176	0.138	0.374	0.086	1.59	4.29	--	4.71	4.86	1.04
K	267	Descent	0.116	0.011	0.210	0.094	1.14	2.52	2.20	1.83	1.89	1.27
		Missed approach	0.052	0.655	0.233	0.029	0.40	4.01	--	2.02	6.12	0.44
H	331	Descent	0.061	0.092	0.219	0.039	0.49	2.33	1.34	1.27	2.08	0.45
		Missed approach	0.182	0.365	0.254	0.013	1.53	3.89	--	1.15	5.06	0.35
M	355	Descent	0.094	0.034	0.294	0.032	0.81	2.76	1.19	3.09	1.07	0.59
		Missed approach	0.163	0.011	0.492	0.038	1.15	5.85	--	1.26	1.89	0.69
K	366	Descent	0.070	0.032	0.184	0.225	0.53	1.62	6.88	0.51	1.00	2.82
		Missed approach	0.125	0.010	0.164	0.007	1.29	2.39	--	2.87	2.02	0.93
TURBULENCE												
G	79	Descent	0.075	0.302	0.222	0.068	0.69	1.65	1.02	1.49	5.20	1.14
		Missed approach	0.082	0.653	0.179	0.133	0.77	3.84	--	1.13	6.54	1.60
H	130	Descent	0.025	0.012	0.146	0.038	0.267	1.54	2.57	1.39	1.57	0.84
		Missed approach	0.158	0.120	0.562	0.030	1.47	7.13	--	4.20	1.69	3.48
G	221	Descent	0.122	0.054	0.221	0.192	1.04	1.91	1.20	2.19	2.88	2.37
		Missed approach	0.145	0.609	0.256	0.046	1.20	4.57	--	1.31	6.75	0.80
K	268	Descent	0.076	0.119	0.181	0.177	0.62	1.46	9.91	1.93	3.51	2.00
		Missed approach	0.175	0.357	0.307	0.042	1.38	3.07	--	6.34	5.60	2.38
H	332	Descent	0.063	0.050	0.174	0.089	0.54	1.44	12.47	1.68	1.96	0.74
		Missed approach	0.232	0.157	0.152	0.051	2.52	2.01	--	4.38	2.86	3.01
M	356	Descent	0.116	0.011	0.261	0.090	0.88	2.62	3.84	2.99	1.97	1.61
		Missed approach	0.073	0.011	0.174	0.013	0.55	1.71	--	1.87	0.90	0.74
K	367	Descent	0.085	0.022	0.106	0.225	0.66	0.66	5.83	2.09	2.21	2.91
		Missed approach	0.223	0.639	0.357	0.091	1.86	6.25	--	2.19	6.99	0.97

TABLE D1.- Continued.

(t) Configuration S25

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	38	Descent	0.105	0.119	0.212	0.010	1.41	2.41	0.67	2.07	2.21	0.69
		Missed approach	0.088	0.468	0.080	0.081	1.81	1.05	--	4.94	6.55	2.42
H	58	Descent	0.036	0.015	0.070	0.021	0.61	1.14	1.75	1.20	1.05	0.40
		Missed approach	0.053	0.063	0.121	0.005	0.72	1.02	--	2.07	1.96	2.48
G	150	Descent	0.052	0.014	0.085	0.080	0.92	1.61	1.77	1.60	1.52	1.10
		Missed approach	0.034	0.012	0.037	0.127	0.91	1.16	--	1.16	1.26	1.84
K	184	Descent	0.131	0.700	0.164	0.038	1.09	1.32	1.11	1.93	8.54	0.90
		Missed approach	0.048	0.772	0.153	0.055	0.37	2.81	--	1.41	7.15	0.79
H	196	Descent	0.008	0.010	0.050	0.012	0.05	0.62	2.70	0.28	0.29	0.11
		Missed approach	0.079	0.013	0.156	0.055	2.14	8.42	--	0.68	1.34	1.01
M	306	Descent	0.088	0.054	0.107	0.029	1.55	2.08	3.98	4.34	2.75	0.82
		Missed approach	0.047	0.011	0.113	0.041	1.20	5.77	--	2.25	1.73	0.91
K	362	Descent	0.045	0.010	0.046	0.171	0.50	1.23	4.78	1.75	0.65	1.97
		Missed approach	0.027	0.212	0.015	0.003	0.35	0.29	--	0.81	2.20	0.50
TURBULENCE												
G	39	Descent	0.099	0.185	0.053	0.073	1.62	0.50	1.31	2.77	5.44	1.16
		Missed approach	0.092	0.317	0.111	0.095	1.16	2.00	--	3.26	5.44	0.95
H	59	Descent	0.042	0.053	0.080	0.035	0.63	1.17	4.24	2.13	1.81	0.83
		Missed approach	0.149	0.256	0.151	0.026	2.60	7.38	--	3.89	3.64	2.11
G	151	Descent	0.045	0.189	0.129	0.071	0.45	2.15	2.18	1.27	2.97	1.03
		Missed approach	0.078	0.653	0.072	0.154	1.12	4.03	--	1.54	6.28	2.18
K	185	Descent	0.110	0.481	0.119	0.090	0.79	1.47	3.08	4.37	4.08	1.13
		Missed approach	0.023	0.572	0.115	0.102	0.22	1.32	--	1.33	5.84	1.14
H	197	Descent	0.055	0.034	0.091	0.057	0.50	2.14	4.42	1.79	1.94	1.10
		Missed approach	0.020	0.092	0.132	0.025	0.50	8.00	--	1.67	1.79	1.97
M	307	Descent	0.089	0.036	0.244	0.074	1.89	3.63	1.67	3.92	3.11	1.05
		Missed approach	0.077	0.535	0.145	0.090	1.45	7.88	--	2.31	5.30	0.85
K	363	Descent	0.114	0.055	0.174	0.272	0.78	2.11	3.62	3.86	2.33	2.89
		Missed approach	0.112	0.011	0.152	0.018	0.99	1.80	--	4.05	2.47	1.43

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A PILOTED SIMULATOR INVESTIGATION OF STATIC STABILITY AND STABI--ETC(U)
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TABLE D1.- Continued.

(u) Configuration S26

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	214	Descent	0.145	0.028	0.193	0.144	1.11	1.07	0.68	1.42	1.97	1.10
		Missed approach	0.216	0.040	0.241	0.045	2.32	2.49	--	2.62	3.76	1.09
H	322	Descent	0.137	0.083	0.140	0.005	1.36	1.74	1.72	2.14	2.78	0.73
		Missed approach	0.279	0.088	0.388	0.018	2.45	4.67	--	3.25	4.79	1.12
K	343	Descent	0.205	0.157	0.299	0.248	1.78	4.96	5.35	1.75	3.71	1.56
		Missed approach	0.318	0.645	0.298	0.106	1.75	10.32	--	1.95	5.36	1.09
TURBULENCE												
G	215	Descent	0.234	0.199	0.341	0.236	2.51	1.75	2.45	4.17	5.71	2.79
		Missed approach	0.242	0.056	0.260	0.079	3.38	1.36	--	4.59	6.29	2.44
H	323	Descent	0.118	0.157	0.206	0.072	1.59	2.33	6.58	4.77	3.72	1.53
		Missed approach	0.483	0.273	0.401	0.032	4.04	9.42	--	5.69	5.95	2.38
K	344	Descent	0.107	0.166	0.263	0.134	0.81	3.05	3.14	2.70	3.07	1.03
		Missed approach	0.158	0.121	0.348	0.132	2.16	6.89	--	4.08	4.02	1.02

TABLE D1.- Continued.

(v) Configuration S27

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	217	Descent	0.135	0.072	0.249	0.036	0.51	1.27	1.66	1.63	0.65	0.60
		Missed approach	0.064	0.011	0.186	0.006	0.13	1.36	--	1.84	0.43	0.44
H	328	Descent	0.157	0.024	0.123	0.071	0.63	0.61	1.28	1.99	0.92	1.21
		Missed approach	0.142	0.141	0.340	0.029	0.49	2.41	--	1.09	1.38	0.49
K	369	Descent	0.168	0.010	0.041	0.142	0.65	0.27	0.69	1.11	1.07	1.18
		Missed approach	0.289	0.805	0.533	0.037	1.09	5.13	--	2.23	7.60	0.63
M	381	Descent	0.353	0.011	0.125	0.036	1.31	0.71	0.89	1.69	2.14	1.38
		Missed approach	0.251	0.011	0.642	0.026	0.61	5.96	--	0.97	1.43	0.68
TURBULENCE												
G	218	Descent	0.299	0.159	0.315	0.083	1.17	1.47	0.69	3.08	4.07	1.09
		Missed approach	0.155	0.048	0.203	0.003	0.47	1.45	--	2.67	0.70	0.68
H	329	Descent	0.145	0.107	0.168	0.068	0.52	0.94	5.25	1.98	1.96	0.80
		Missed approach	0.417	0.207	0.313	0.040	1.41	2.70	--	2.56	2.45	0.70
K	370	Descent	0.195	0.011	0.075	0.141	0.64	0.32	2.03	3.47	2.26	1.47
		Missed approach	0.437	0.611	0.618	1.09	1.71	5.27	--	6.18	6.06	2.20
M	382	Descent	0.330	0.147	0.253	0.076	1.26	1.71	3.30	4.88	2.85	1.66
		Missed approach	0.362	0.324	0.725	0.028	1.46	5.95	--	5.34	4.43	1.49

TABLE D1.- Continued.

(w) Configuration S28

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	69	Descent	0.053	0.418	0.108	0.014	1.49	1.20	0.90	1.93	5.51	0.43
		Missed approach	0.105	0.805	0.110	0.010	2.25	5.03	--	3.98	5.84	1.34
H	102	Descent	0.089	0.060	0.122	0.043	0.69	1.21	0.93	2.56	1.01	0.55
		Missed approach	0.142	0.041	0.265	0.058	1.40	7.35	--	3.75	2.49	0.97
K	273	Descent	0.202	0.125	0.053	0.059	2.04	0.67	1.84	2.96	4.32	0.63
		Missed approach	0.175	0.073	0.068	0.010	0.76	0.57	--	1.40	1.47	1.13
TURBULENCE												
G	70	Descent	0.061	0.204	0.166	0.045	1.60	1.72	4.91	1.64	3.98	0.99
		Missed approach	0.054	0.817	0.079	0.098	1.13	4.89	--	3.41	7.98	0.91
K	274	Descent	0.175	0.011	0.389	0.287	0.67	2.86	2.51	1.98	1.53	1.77
		Missed approach	0.129	0.771	0.171	0.042	1.63	6.62	--	1.72	6.65	1.56

TABLE D1.- Continued.

(x) Configuration S29

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	241	Descent	0.240	0.011	0.178	0.069	2.52	2.37	14.97	6.05	4.12	6.36
		Missed approach	0.489	0.128	0.299	0.058	4.24	9.66	--	4.00	8.04	2.89
K	334	Descent	0.139	0.010	0.186	0.050	1.61	1.83	1.64	2.13	2.70	1.30
		Missed approach	0.330	0.779	0.230	0.093	2.18	7.65	--	4.29	8.29	2.31
TURBULENCE												
H	243	Descent	0.527	0.421	0.316	0.088	3.45	2.48	16.41	5.77	8.02	4.53
		Missed approach	0.259	0.061	0.275	0.072	5.73	9.62	--	2.98	3.48	3.27
K	335	Descent	0.209	0.091	0.124	0.082	1.83	1.51	12.60	3.22	4.87	1.95
		Missed approach	0.389	0.825	0.275	0.103	3.85	8.09	--	5.99	11.43	2.79

TABLE D1.- Continued.

(y) Configuration S30

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ϵ_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
G	207	Descent	0.091	0.321	0.116	0.027	0.79	1.02	0.46	0.99	4.63	1.60
		Missed approach	0.153	0.096	0.234	0.054	0.79	2.45	--	1.50	2.49	4.21
H	245	Descent	0.323	0.010	0.240	0.066	1.59	2.32	12.73	3.16	2.91	2.14
		Missed approach	0.370	0.138	0.424	0.142	2.28	4.73	--	3.91	5.68	5.51
K	340	Descent	0.200	0.211	0.140	0.147	0.71	1.32	0.82	5.83	2.07	2.30
		Missed approach	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	--	n.a.	n.a.	n.a.
TURBULENCE												
G	208	Descent	0.203	0.123	0.282	0.056	0.88	2.33	2.43	2.95	2.50	1.06
		Missed approach	0.395	0.011	0.130	0.076	2.32	1.26	--	4.02	0.94	6.04
H	246	Descent	0.344	0.053	0.194	0.047	1.61	1.11	1.50	3.63	2.29	3.52
		Missed approach	0.839	0.232	0.738	0.133	4.17	9.72	--	3.96	6.37	5.28
K	341	Descent	0.149	0.028	0.066	0.091	0.74	0.38	5.15	2.68	2.01	1.73
		Missed approach	0.260	0.743	0.460	0.040	2.01	5.57	--	3.57	7.96	3.29

TABLE D1.- Concluded.

(z) Configuration S31

Pilot	Run	Segment	Standard deviation									
			δ_{ES}	δ_{CS}	δ_{AS}	δ_{RP}	θ	ϕ	ε_{VOR}	V	$\dot{h}$	β
NO TURBULENCE												
H	248	Descent	0.068	0.049	0.148	0.064	0.97	1.62	1.88	2.96	1.96	6.06
		Missed approach	0.324	0.620	0.317	0.048	5.39	8.69	--	1.74	7.11	4.76
K	337	Descent	0.083	0.127	0.038	0.021	0.12	0.33	1.20	1.84	1.81	0.51
		Missed approach	0.239	0.705	0.450	0.033	1.49	6.14	--	1.31	8.27	1.84
TURBULENCE												
H	249	Descent	0.136	0.120	0.113	0.104	1.38	1.41	1.97	3.10	3.30	6.67
		Missed approach	0.156	0.123	0.235	0.043	2.89	9.13	--	2.38	2.49	4.03
K	338	Descent	0.143	0.122	0.147	0.192	0.43	1.27	5.65	1.84	2.57	3.73
		Missed approach	0.210	0.749	0.536	0.200	2.12	6.42	--	3.82	9.03	2.01

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16. Abstract

A motion-base simulator was used to compare the flying qualities of three generic single-rotor helicopters during a full-attention-to-flight control task. Terminal-area VOR instrument approaches were flown with and without turbulence. The objective of this NASA/FAA study was to investigate the influence of helicopter static stability in terms of the values of cockpit control gradients as specified in the existing airworthiness criteria, and to examine the effectiveness of several types of stability control augmentation systems in improving the instrument-flight-rules capability of helicopters with reduced static stability. Two levels of static stability in the pitch, roll, and yaw axes were examined for a hingeless-rotor configuration; the variations were stable and neutral static stability in pitch and roll, and two levels of stability in yaw. For the lower level of static stability, four types of stability and control augmentation were also examined for helicopters with three rotor types: hingeless, articulated, and teetering. Pilot rating results indicate the acceptability of neutral static stability longitudinally and laterally and the need for pitch-roll attitude augmentation to achieve a satisfactory system.

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